Aarhus School of Business, Aarhus University

Master of Science in International Economic Consulting

Master Thesis

Overcoming Barriers to Rural Electrification

An Analysis of Micro-Energy Lending and its Potentials in the International Carbon Market on the Example of Solar Home Systems in Bangladesh

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Currency Equivalents

Currency Unit = Bangladeshi Taka (BDT) & United States Dollar (US$)

1 US$ = BDT 70.48

1 US$ = EUR 0.76

List of Abbreviations

CBA	Cost Benefit Analysis
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COP	Conference of the Parties
CPA	CDM Programme Activity
DD	Design Document
EB	Executive Board
EE	Energy Efficiency
ERPA	Emission Reduction Purchase Agreement
EU ETS	European Emission Trading System
GEF	Global Environment Facility
GHG	Greenhouse Gas
HDI	Human Development Index
ICT	Information and Communications Technology
IDA	International Development Association
IDCOL	Infrastructure Development Company Limited
IPCC	Intergovernmental Panel on Climate Change
ISEP	IDCOL Solar Energy Programme
KfW	Kreditanstalt für Wiederaufbau (German Development Cooperation)
kgoe	kilograms of oil equivalent
kt	kiloton (equal to 1,000 metric tones)
kWh	Kilowatt hour
LDC	Least Developed Country
LPG	Liquefied Petroleum Gas
MCA	Multi-Criteria Analysis

MDG	Millennium Development Goal
MEL	Micro-Energy Lending
MF	Microfinance
MFI	Microfinance Institution
MIX	Microfinance Information Exchange
MW	Megawatt
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
pCDM	programmatic CDM (equivalent to PoA)
PDD	Project Design Document
PIN	Programme Idea Note
PoA	Programme of Activities (equivalent to pCDM)
PV	Solar Photovoltaic
RE	Renewable Energy
REREDP	Rural Electrification and Renewable Energy Development Project
SHS	Solar Home System
SME	Small and Medium Enterprises
$MtCO_2e$	Million metric tonnes of Carbon Dioxide equivalent
UNFCCC	United Nations Framework Convention on Climate Change
VSSC	Very small-scale projects
WCED	World Commission on Environment and Development
Wp	Watt peak

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Abstract

Climate change and energy poverty are major impediments to the development of rural areas in developing countries. And the two challenges are interlinked: Energy-related activities are the major source of carbon emissions and the provision of electricity for rural off-grid areas requires large extensions of energy services. Therefore, development mechanisms that address barriers to rural electrification and promote low-carbon development are needed.

This thesis explores how the combination of micro-energy lending and carbon finance can overcome barriers to rural electrification and renewable energy sources. In particular, it analyses how micro-energy lending projects can be linked to and benefit from the Kyoto Protocol's Clean Development Mechanism (CDM) and how these projects promote sustainable development.

Based on expert interviews with carbon market, microfinance and rural electrification experts a theoretical analysis of the linkages between micro-energy lending and carbon project cycles is conducted. A case study of the IDCOL Solar Energy Programme in Bangladesh, regarded as one of the most successful rural electrification programmes in the world, substantiates the analysis. It is complemented by a Multi-Criteria Analysis, which evaluates the programme's contribution to sustainable development and the performance of the programme as such.

The author finds that microfinance infrastructure can very well integrate with and promote Programmes of Activities (PoA), a specific approach under the CDM, and CDM monitoring procedures. Synergies between micro-energy lending and carbon project cycles reduce CDM transaction costs, which are often prohibitive for small-scale projects to register under the CDM and the combination of the two financing mechanisms addresses major barriers to rural electrification, most importantly the lack of infrastructure, the lack of access to credit for end-users and high upfront costs. But the major CDM-related barriers for small-scale projects, high transaction costs and complexity, remain obstacles under the PoA approach. Carbon finance only marginally improves the economic viability of micro-energy projects and does thus not overcome cost barriers to rural electrification. However, solar home systems (SHS) achieve significant cost savings for rural households and provide clean energy for lighting, communication, information and entertainment. Carbon emission reductions of SHS are marginal on a global scale but SHS achieve the goal of low-carbon development. To ensure sustainability on the project level, micro-energy projects must provide high-quality technology, proper training and maintenance services as well as strong credit risk management.

1 Introduction

Global climate change and poverty in developing countries are probably the most serious challenges the world is facing today (Rippey, 2009; Watkins & UNDP, 2007). On top of that, the successful mitigation of climate change and the promotion of poverty reduction through development are *"twin challenges"* (Baer et al., 2008) that cannot be addressed independently from each other. Climate change threatens development progress as impacts of global warming are more severe and people are more vulnerable in developing countries (Baer et al., 2008; Stern, 2008; World Bank, 2009). In addition, traditional development paths are more and more questioned by ecologists and environmental economists, as the resource- and carbon-intensive economic growth industrialized countries went through contributed significantly to global warming. As a consequence, tackling climate change requires developing countries to adopt sustainable, low-emission growth paths (Baer et al., 2008; FitzRoy & Papyrakis, 2010; IPCC, 2007; Munasinghe, 2009). New economic mechanisms and instruments must be developed that simultaneously address climate change and poverty through sustainable development. Micro-energy lending (MEL), the approach the thesis at hand is intended to analyse, promises to be such an instrument addressing climate change mitigation and energy poverty – often one dimension of poverty in developing countries.

The focus of this thesis is on the micro-level, or more precisely on mitigation activities by households and micro-businesses, which at the same time foster development. One essential requirement for development and poverty reduction is energy (Ilskog & Kjellström, 2008; Ilskog, 2008; Rao et al., 2009; UNEP, 2007a). Having no access to modern energy services, such as electricity, impedes *"opportunities for economic development and improved living standards"* (Munasinghe, 2009). Many studies emphasize the key role of modern energy for the achievement of the Millennium Development Goals (MDGs) (among others AGECC, 2010; Ilskog, 2008; Legros et al., 2009; Modi, 2004). Probably the most important benefit of clean energy is the reduction of indoor air pollution, leading to more than 1.9 million deaths per year (Legros et al., 2009). Still, nearly 1.5 billion people (IEA, 2008a) in developing countries have no access to electricity, clearly showing the scale of global energy poverty. The majority of energy-starved households is located in rural areas (Legros et al., 2009; World Bank, 2008a). The further dissemination of electricity grid connection or decentralized energy systems faces a number of barriers, and limited access to finance represents the primary

gap. This is where microfinance (MF) intervention could overcome a barrier and provide micro-energy loans in order to enable poor households and small enterprises, especially in rural areas, to finance access to energy (Aron et al., 2009; Beck & Martinot, 2004; Urmee et al., 2009).

But due to climate change, the challenge is two-fold: Energy needs of those lacking access to modern energy services have to be met while a global transition to low-carbon energy systems has to be achieved (Ahuja & Tatsutani, 2009). On a global level, industrialized countries have to make the largest mitigation effort (Baer et al., 2008) but it should also be in the interest of developing countries *"to avoid locking into a high-carbon infrastructure"* (World Bank, 2009) in order to achieve sustainable development without putting further pressure on the climate. Both, low-carbon energy production and the expansion of rural energy services can be achieved by a more intensive use of renewable energy (RE) sources (Munasinghe, 2009), which is the focus of this thesis. In particular, the focus is on rural off-grid electrification with solar home systems (SHS), often a viable alternative to grid extension (REN21, 2010). It should be clear that for the rural poor improvement of living standards has priority, whereas climate change mitigation plays a minor if any role (Modi, 2004).

Although MF intervention for energy access addresses one financial barrier, namely the lack of access to credit for poor households and micro-businesses, high initial capital costs, limited capacity and familiarity with RE technologies remain major obstacles for rural electrification (Beck & Martinot, 2004). In order to make RE economically viable for households and micro-businesses, further financial resources are needed. One opportunity analysed in this thesis is to couple MEL with the international carbon market in order to generate carbon revenues from emission reductions (Bahnsen et al., 2009; Hayashi et al., 2010; Rippey, 2009). To date the only mechanism under the Kyoto Protocol involving developing countries in mitigation activities is the Clean Development Mechanism (CDM), which aims at both emission reductions and sustainable development co-benefits. Renewable, modern energy sources promoted by MEL promise significant development benefits, suggesting that synergies between these instruments should be utilized more effectively (Dowla, 2009). The most promising tool under the CDM is the Programme of Activities (PoA), a specific project type also known as the programmatic CDM (pCDM), allowing for an aggregation of emission reductions from a number of projects and thus addressing high transaction costs, which pose a barrier for micro-scale projects in the CDM market (see also Boyd et al., 2009).

The pCDM offers potential sources of carbon revenues for MEL projects but research as well as project cases in this area are sparse. The literature on the CDM states that *"further research in planned and ongoing projects* [is needed] *in order to improve sustainable development benefits through CDM"* (Boyd et al., 2009). The authors add that rural electrification projects especially contribute to sustainable development but are rare in the CDM project pipeline. Other papers explicitly recommend MF as a financial mechanism for small-scale CDM projects without going into a deeper analysis of the suitability of project requirements for MEL (e.g. Heeren & Karcher, 2010; van der Gaast et al., 2009). A study analysing the potential synergies between the pCDM and MF points out that *"there is a need to investigate further and demonstrate ... how CDM funds in combination with* [microfinance] *can improve the economic viability of a project"* (Bahnsen et al., 2009). Accordingly, further research on MEL and its potentials under the CDM is needed. This thesis aims at contributing to the applied research on this particular field from an economic and a sustainable development perspective.

The core problem addressed can be stated as follows: What opportunities does the programmatic CDM offer for MEL projects and how do these projects promote sustainable rural development? The objective of this thesis is to investigate opportunities and consequences by addressing the following research questions:

(1) WHAT OPPORTUNTIES does the combination of micro- and carbon finance offer to rural electrification and WHAT BARRIERS do projects face?

(2) HOW do carbon revenues improve the economic viability of micro-energy projects and do they justify high upfront and monitoring costs?

(3) WHAT CONSEQUENCES does micro-energy lending have in respect to social and environmental benefits, i.e. does it promote sustainable rural development?

The methodological approach combines a theoretical analysis of linkages between MEL and carbon project cycles as well as a case study of a MEL project promoting solar home systems (SHS) in Bangladesh. As a source of primary data the theoretical analysis draws on expert interviews with carbon market, microfinance and rural electrification experts. For the case study a multi-criteria analysis (MCA) based on quantitative data substantiated with comprehensive qualitative information from stakeholder interviews, field visits and internal documents is conducted. The set of indicators for the MCA is defined according to sustainomics principles presented by Munasinghe (2004; 2009)

and includes indicators for economic, social, environmental, institutional and technological sustainability.

To the best knowledge of the author, no other paper has presented such a comprehensive analysis of the combination of MF and carbon finance or such a thorough evaluation of a MEL project. The author finds that MF infrastructure can very well integrate PoA projects and CDM monitoring procedures and that synergies reduce CDM transaction costs. Most importantly, the combination of the two financing mechanisms addresses major barriers to rural electrification, the lack of infrastructure, the lack of access to credit for end-consumers and high upfront costs. However, the major barriers of the CDM for small-scale projects, high transaction costs and complexity, remain obstacles under the pCDM. Improvements of the economic viability of micro-energy projects through carbon finance are marginal and revenue streams of the CDM are not well matched with financial needs of MEL projects. SHS achieve significant cost savings for the rural poor but impacts on economic development are limited compared to grid-electrification. Still, SHS clients value high-quality lighting and some use electricity for productive purposes. Greenhouse gas (GHG) emission reductions of SHS are marginal but achieve the goal of low-carbon development. On the project level, micro-energy projects must ensure longevity of technology through proper training and maintenance services and strong risk management, as energy loans are related to a higher credit risk than other microloans.

The thesis is structured as follows: The second chapter presents the relevant theoretical background as well as a literature review on MEL. The chapter ends with a summary of the implications for MEL and its coupling to the carbon market derived from the literature. The third chapter introduces the applied methodology and provides an overview of the data used for the analyses and how they were collected. The theoretical analysis of the linkages between MEL and the pCDM is conducted in the fourth chapter. The fifth chapter presents the case study and the MCA of the project in Bangladesh. Chapter six concludes by linking the results from the two parts and presents suggestions for further research.

2 Theoretical Background & Literature Review

An analysis of MEL and its potentials in the international carbon market combines different research fields and theories. It requires a clear understanding of the role of energy in the development process, the implications of climate change for future energy systems, and how MF and carbon finance can function as financing mechanisms for rural electrification. This chapter provides an overview of these topics and builds the theoretic background for the analysis. The chapter begins by introducing the concept of sustainable development, building the framework for the MEL approach and in a broader sense outlines development opportunities in times of climate change.

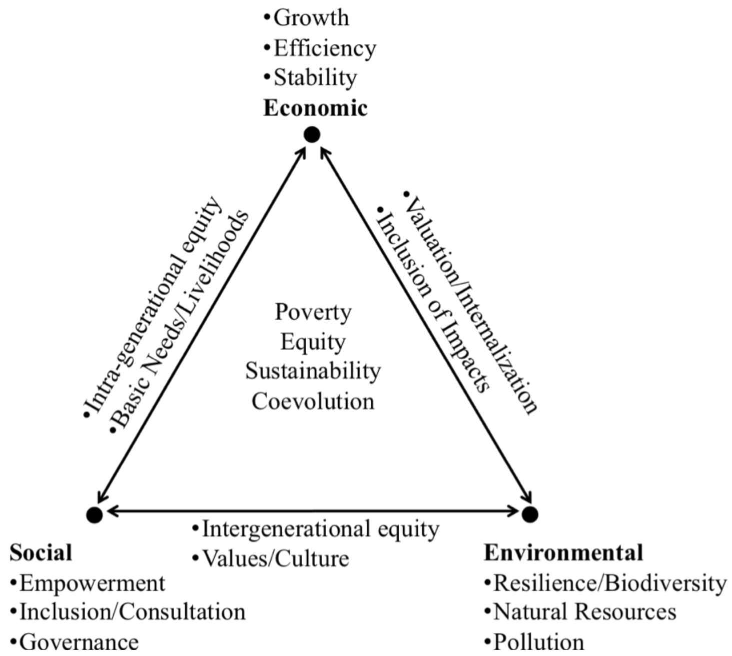
2.1 The Concept of Sustainable Development

Development can broadly be defined as *"the process of furthering people's well being"* (UNEP, 2007b). Increasing environmental degradation and convincing evidence that human activity exploits natural capital at non-sustainable rates has contributed to the perception that functioning eco-systems are prerequisites for long-term development (Dasgupta, 2010; UNEP, 2007b). Climate change in particular has demonstrated that development opportunities are limited when global warming proceeds without mitigation and that future development must follow a different path than the carbon- and resource-intensive growth path followed by industrialized countries (Baer et al., 2008; Dasgupta, 2010; World Bank, 2009).

The framework of sustainable development defines the parameters for an economic development approach in accordance with social and environmental needs (UNEP, 2007b). The basics of the framework were set with the publication of the Report of the World Commission on Environment and Development in 1987, known as the Brundtland Report. Here, sustainable development was defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987). Climate change, having a significant impact on development opportunities of developing countries today and even more in the future clearly is incompatible with this definition. (World Bank, 2009). Also poverty and intra-generational inequality are repugnant to sustainable development, making climate change mitigation and poverty alleviation key requirements for future development progress (Watkins & UNDP, 2007).

The most applied notion of sustainability is the triple-bottom line defined by the sustainable development triangle firstly introduced at the Earth Summit in Rio de Janeiro in 1992. The triangle, amongst others presented in Munasinghe (2009) and Munasinghe (2004) defines an economic, social and environmental dimension building a transdisciplinary framework for development strategies and projects.

Figure 1: Dimensions of Sustainable Development



Source: Adapted from Munasinghe (2009).

Each of the three dimensions is equally important. The main driver of the economic system is economic efficiency measured against Pareto optimality. The social system is striving for individual well-being and overall social welfare, while a functioning environmental system, on which ultimately both the economic and the social system depend, relies on a responsible use of environmental resources (Munasinghe, 2009). Though it can be criticised that the approach did not manage to displace the one-dimensional growth paradigm nor to significantly change economic behaviour, for example in the context of climate change (Martinez-Alier et al., 2010), it offers a suitable framework for project analyses and is applied in the further context of this thesis.

In the context of sustainable development, energy plays a key role in all three dimensions (Munasinghe, 2004) and it is at the heart of the MEL approach. The next section outlines the relationship between energy and development and gives an introduction to rural electrification.

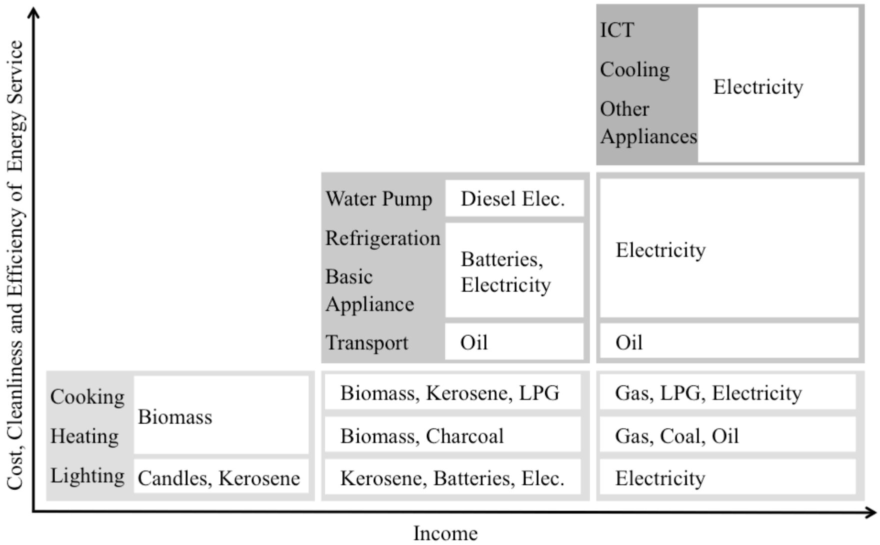
2.2 Energy and Development

It is widely acknowledged that energy and development are closely related to each other. But especially in rural areas the provision of energy services remains a challenge. In order to create an understanding of the importance of energy in the development process, this section presents the strong relationship between energy and development and puts rural electrification in a sustainable development context. Additionally, barriers for rural electrification and renewable energy technologies are outlined.

2.2.1 Energy Access for Sustainable Development

Energy access is key to development and *"no country has managed poverty alleviation without increasing energy access"* (Rao et al., 2009). Expressed in numbers 300 million households, and thereof 260 million in rural areas, do not have access to electricity (World Bank, 2008a). Another billion only has access to instable electricity networks (AGECC, 2010). In 2008, the rural electrification rate in developing countries was only 58.4%, with the lowest rates in sub-Saharan Africa (11.9%) and South Asia (48.4%). Urban electrification rates are significantly higher reaching 90% in developing countries (IEA, 2008a). The numbers show that rural communities especially suffer from energy poverty and are on the lowest rung of the energy ladder, a concept describing the transition from traditional to modern energy sources. According to this concept, development on the household level is associated with both higher energy consumption and changes in the energy mix toward higher percentages of modern energy. But a universal energy ladder with identical rungs does not exist. A further implication confirmed by econometric evidence is a positive relationship between energy consumption and household income, (Hosier, 2004).

Figure 2: The Traditional Energy Ladder



Source: Revised from Hosier (2004) and Duflo et al. (2008).

Moving from the household to the national level, the correlation between energy and economic development has been investigated in depth by vast empirical studies. Results indicate a close, positive relationship for developing countries and a decreasing relationship for developed countries due to EE gains (Munasinghe, 2009; Stern, 2004). Further empirical evidence confirms positive impacts of energy on the Human Development Index (HDI), which measures economic and social development combining life expectancy, education and per-capita GDP. Effects are especially strong in early development stages but begin to decline after a certain threshold (Goldemberg, 2004).

A great number of studies (Agbemabiese, 2009; AGECC, 2010; Modi, 2004; OECD/IEA, 2010; UNEP, 2007a) points to the importance of modern energy services in order to meet the MDGs[1]. No goal explicitly addresses energy access but it is currently under discussion to adopt the goal of universal energy access by 2030 (OECD/IEA, 2010). In terms of poverty alleviation, Khandker et al. (2009) investigate the impacts of rural electrification in Bangladesh and come to the conclusion that it has significant positive development impacts, such as increased household income and expenditure as well as better schooling outcomes. Another study by Dinkelmann (2008) finds that rural electrification in South Africa successfully contributes to female employment rates.

Energy not only has strong implications for the economic and social, but also for the environmental dimension of sustainable development (Munasinghe, 2009). When

[1] The MDGs and the impact of modern energy and climate change on the MDGs is provided in the appendix.

developing countries would climb up the same energy ladder as industrialized countries did, limited resources and a strong increase of carbon emissions would put major stresses on the environment (Hosier, 2004). Furthermore, the relationship between energy and economic growth implies a strong correlation between development and CO_2 emissions, as energy-related activities, first and foremost the use of fossil fuels, are still the major source of carbon emissions (Munasinghe, 2004; UNEP, 2007b). Thus, successful climate change mitigation requires a *“dramatic shift toward renewable energy”* (World Bank, 2009) in order to decouple development progress and GHG emissions. Though the provision of basic energy services on a universal level would increase global emissions of only 1.3%, further development progress could increase emissions significantly (AGECC, 2010). And there are good reasons why developing countries should promote low-carbon technologies: The deployment of RE technologies prevents the lock-in into a high-carbon infrastructure, reduces the dependence on fossil-fuel imports and price fluctuations and accelerates off-grid electrification where grid connection is no option (Agbemabiese, 2009; REN21, 2010; World Bank, 2009). Some recent studies address the impact of rural electrification on sustainable development (examples are Agbemabiese, 2009; Ilskog & Kjellström, 2008; Ilskog, 2008) and come to the conclusion that it is key for low-carbon development progress. However, barriers for the further dissemination of RE technologies remain. These are presented in the next section.

2.2.2 Barriers for Rural Electrification and Renewable Energy Technologies

For rural and remote areas in developing countries grid connection often is economically prohibitive or a potential scenario in the far distanced future. A promising alternative has evolved with the maturation of small-scale stand-alone systems (World Bank, 2008a). Micro-energy systems generate energy locally and facilitate decentralized energy generation (Phillip & Schäfer, 2009). In the rural transition from traditional to modern energy sources RE-based micro systems, such as solar photovoltaic (PV) systems, biogas digesters, small wind or micro hydro mini-grids, play a key role as they offer cost-efficient alternatives to grid extension and an environmentally friendly source of modern energy (Agbemabiese, 2009; REN21, 2010; World Bank, 2008a). The technology predominantly used for off-grid electrification is solar PV in the form of SHS, which are also the focus of the case study presented in this thesis. In most developing countries sunlight is an abundant resource making SHS an attractive and

cost-effective technology, although PV technology still requires the highest investment cost among commercially deployed RE technologies (Adib et al., 2001; IEA, 2008b; van der Vleuten et al., 2007). Nearly 3 million households have access to electricity from small solar PV systems today (REN21, 2010).

Most importantly, SHS provide clean electricity for lighting and depending on the size also for modern communication, information and entertainment, such as TV, radio and cell phone (van der Vleuten et al., 2007). The substitution of kerosene or diesel lanterns has important health benefits due to reduced in-house air pollution and risk of fire. SHS can serve micro-enterprises or home-based income-generating activities and lead to better education outcomes when lighting is used for extended study hours (AGECC, 2010; REN21, 2010). A common criticism is that SHS often do not benefit the poorest of the poor, as they cannot afford high upfront costs (Jacobson, 2007; van der Vleuten et al., 2007). However, this is the same with grid electrification where connection costs pose a barrier (World Bank, 2008b). But there can still be positive side-effects for poorer members of the community, for example when SHS provide electricity for schools, health centres or communication services or when micro-businesses evolve as a consequence of rural electrification (Khandker et al., 2009; Modi, 2004; World Bank, 2008a).

Although technological solutions can overcome the barrier of remoteness, rural electrification remains a challenge. Barriers to RE technologies and rural electrification can be divided into three broad categories and are presented in the table below.

Table 1: Barriers to Renewable Energy and Rural Electrification

Economic and Financial Barriers
High initial upfront costs for end-users and providers
High Transaction Costs
Subsidies for fossil fuels and non-renewables
Environmental Externalities
Market Performance Barriers
Lack of Access to Credit
Lack of Market Infrastructure & Distribution Network
Lack of Capacity & Information
Legal and Regulatory Barriers
Lack of Level Playing Field between RE and Conventional Energy
Lack of Industry-Wide Technical Standards

Source: Author based on Beck & Martinot (2004) and World Bank (2008).

Most important economic and financial barriers in the context of micro-energy projects are high initial capital costs providing less installed capacity per invested dollar

compared to conventional energy sources, subsidies for fossil fuels and other non-renewables, high transaction costs due to unfamiliarity and lack of information, and environmental externalities of fossil fuel-based technologies distorting costs to society (Beck & Martinot, 2004; World Bank, 2008). Rural-electrification often is a loss-making venture. People living in remote areas are usually poorer than those living in urban areas and technological off-grid solutions require higher initial investments. In most cases, subsidies are required to cover initial investment or even operating costs (AGECC, 2010). Relevant market performance barriers for RE projects are the lack of access to credit for project developers and consumers as well as the lack of technical and commercial skills needed for installation, operation and maintenance. Even if MF services are available, loan conditions and duration may not be appropriate for energy-lending (Beck & Martinot, 2004). Other specific rural-market performance barriers for the creation of commercial RE markets are the development of dispersed market structures, functioning maintenance infrastructures and the lack of skilled personnel (van der Vleuten et al., 2007; World Bank, 2008). Legal and regulatory barriers are not outlined any further as they are not the focus of this thesis.

Despite of the barriers faced by rural electrification projects successful examples exist. More recently, rural electrification projects tend to integrate private industries and to build up market infrastructures, instead of purely relying on development aid (Adib et al., 2001). Experience with off-grid SHS electrification has shown that strong linkages to the local private sector are most promising to establish sustainable business models and delivery mechanisms. Next to a market-based dissemination model, financing mechanisms and functioning after-sales services for operation and maintenance are key to the long-term project success (van der Vleuten et al., 2007; World Bank, 2008a). Trends in financing tend to integrate local institutions, such as private or public banks, which in turn provide funds to private companies, NGOs or MFIs offering an energy-product portfolio (REN21, 2010).

To sum up, technologies for rural electrification contributing to sustainable rural development and best-practice delivery mechanisms exist. Financing remains the major obstacle for the rural poor, local markets and project developers. As the application of RE technologies leads to GHG emission reductions, carbon revenues provide a potential source of additional finance. The next section offers an introduction to the economics behind carbon trading and the CDM, a mechanism enabling developing countries to participate in the international carbon market.

2.3 Carbon Finance for Sustainable Development

Developing and least developed countries (LDCs)[2] not only suffer most from the consequences of climate change, they also contributed least to global warming nor do they have the financial capability to mitigate or adapt to climate change (Baer et al., 2008; Watkins & UNDP, 2007). In order to finance development with low-carbon technologies the integration of developing countries into the international carbon market is one opportunity to enable them to benefit from carbon finance. This section intends to create a clear understanding how the carbon market can serve as a financing mechanism for MEL projects.

2.3.1 Economics of Climate Change and Carbon Trading

From an economic perspective climate change is caused by a negative externality, as a consequence of market failures in energy and other carbon-intensive markets (DeCanio, 2004). One policy option to internalize the external costs to society is to put a price on carbon, for example, by implementing market-based instruments creating incentives for emission reductions. Such price-driven instruments enable market agents to reduce emissions in a cost efficient manner (Kolstad & Toman, 2005) and provide flexibility in terms of how, when and where emission reductions are achieved and thus reduce marginal abatement costs (Stern, 2008). Carbon trading builds on a cap-and-trade system as an instrument for carbon pricing, where the cap is defined as a limit of carbon emissions and an equal number of emission allowances can be traded between market participants. Price determination is left to the market with this approach (Keohane, 2009). Of major relevance is the fact that emissions trading under a cap-and-trade system allows to implement emission reduction projects in least-cost locations and thus generates financial flows into developing countries (Stern, 2008). Governments or companies having a legally binding cap defined by national or international climate policy can buy emission reductions stemming from projects in developing countries, and thus offset emissions (Carraro & Favero, 2009).

Carbon offsetting, i.e. the compensation of a specific amount of GHG emitted at one location by the reduction of an equal amount of emissions at another location (Butzengeiger, 2005), must ensure environmental integrity in order to be effective. In particular, emission reductions must be quantifiable, verifiable and additional (Kollmuss

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[2] The term ‘developing countries’ includes LDCs if not stated otherwise. The appendix provides a list of LDCs.

et al., 2008). According to the Kyoto Protocol, additionality is given when emission reductions would not occur in the absence of the project activity (UNFCCC, 1998). Quantification of emission reductions relies on a hypothetical baseline scenario demonstrating *"what would have occurred had the activity not been implemented as an offset project"* (Kollmuss et al., 2008). Though offsetting does not reduce overall CO_2 emissions, which is of major importance in order to keep warming below the widely accepted maximum of 2°C of pre-industrial temperatures (Baer et al., 2008; DEHSt, 2008; UNFCCC, 2010f), the impact of clean energy and development co-benefits can be considerable for the rural poor (DEHSt, 2008; Kollmuss et al., 2008).

2.3.2 The International Carbon Market

The largest carbon market in the world is regulated under the Kyoto Protocol, which is the only international climate agreement involving binding emission reductions targets for industrialized (Annex I) countries for the period from 2008 to 2012[3] (FitzRoy & Papyrakis, 2010). The Protocol provides three flexible mechanisms, Joint Implementation and the CDM, both project-based offset-mechanisms, and emissions trading organised as a cap-and-trade system (FitzRoy & Papyrakis, 2010). The CDM is the only mechanism involving developing countries in mitigation activities and therefore the focus of this paper.

Next to assisting Annex I countries in achieving their emission reduction targets in a cost-efficient way by using Certified Emission Reductions (CERs) generated under the CDM, the explicit objective of the CDM is the achievement of sustainable development benefits in developing countries (Kolstad & Toman, 2005). But several studies claim that there are no or only insufficient contributions to sustainable development (Olsen, 2007; Streck, 2009), which is predominantly due to the fact that co-benefits are not monitored and that definition is up to host countries (Olsen & Fenhann Jørgen, 2008; Sterk et al., 2009). In the CDM portfolio, rural electrification projects seem to contribute more to sustainable development than other project activities but are rare in the project pipeline (Boyd et al., 2009). In general, the CDM is criticised for high transaction costs that pose a barrier for dispersed micro-activities and for the unequal distribution of project activities among developing countries (Boyd et al., 2009; van der

[3] The CDM will exist even after 2012 (UNFCCC, 2010g) and post-2012 demand for carbon credits is guaranteed by the European Trading System (EU ETS) at least until 2020 (EU, 2009).

Gaast et al., 2009). Predominant host countries of CDM projects are in a descending order China, India, Brazil and Mexico, together accounting for about 75% and China alone for about 40% of all projects (author's calculations based on UNEP Risoe Centre, 2010). Due to the absence of huge industries and their low capacity LDCs are rarely host countries of CDM projects. Here, demand-side RE or energy efficiency (EE) projects, characterised as dispersed micro-activities on the household or micro-enterprise level, comprise significant emission reduction potential but high transaction costs avert registration (Smuda & Karschunke, 2009). Consequently, micro-activities in LDCs are underrepresented among stand-alone CDM projects (Hayashi et al., 2010).

In order to address these major criticisms of the CDM, a programmatic approach was introduced, which is particularly suitable for demand-side RE and EE projects (Kossoy & Ambrosi, 2010). The PoA approach got operational in 2007 with the objective to extend CDM project types from stand-alone projects to *"replicable projects with low and physically spread GHG emissions reductions activities"* (Hinostroza et al., 2009). It allows for an aggregation of emission reductions from dispersed micro-activities and can thus reduce transaction costs through economies of scale making it potentially the most important instrument under the CDM for LDCs (Hayashi et al., 2010). But though the preliminary trend indicates that the PoA changes regional patterns, in the PoA pipeline projects in LDCs account for 10.2% in contrast to only 1.1% of the CDM pipeline[4] (author's calculations based on UNEP Risoe Centre, 2010) major difficulties to register PoA projects indicate that further streamlining of regulations is needed (Hayashi et al., 2010). By now, only five PoAs managed to get registered and 54 are under validation, some since more than two years (UNEP Risoe Centre, 2010). This links to another major criticism of the CDM, which is directed at its inefficient and slow processes posing a risk for investors and project owners (Streck, 2009) and indicating that financial barriers are not the only obstacles for LDCs or micro-energy projects to benefit from the CDM.

It is important to emphasise that although the CDM is target of a lot of criticism it is declared a success as it has generated more low-carbon finance for developing countries than any other mechanism and it is supported by developing nations' governments (Streck, 2009). In addition, the PoA approach bears the potential to overcome some of

[4] For sound statistical analyses of the PoA much more registrations would be needed. The comparison is based on a total of 59 PoA and 5,619 CDM projects in the pipeline, including registered projects and those under validation.

the CDM barriers and is *"seen as one central element … to further tap the untapped potential of greenhouse gas mitigation options in Least Developed Countries"* (Hayashi et al., 2010).

In summary, by generating tradable CERs the carbon market can serve as a financing mechanism contributing to the financial viability of rural electrification projects. However, another mechanism is needed in order to make micro-energy systems affordable for rural populations. MF could be one tool to overcome imperfect credit markets for end-users and promote carbon projects (Bahnsen et al., 2009; Hayashi et al., 2010). Exploring potential synergies between MF and the pCDM was also recommended by the CDM Executive Board (CDM EB) as one possibility to address the unequal regional distribution of CDM projects (UNFCCC, 2010b). An introduction to MF is presented in the next paragraphs and synergies are further analysed in the remainder of this thesis.

2.4 Microfinance as a Development Tool

MF is generally known as the provision of financial services for the poor and usually comprises micro-credits as well as savings (Robinson, 2001). Two events especially contributed to the broad public awareness of MF and demonstrated the high expectations on the development impact, the International Year of Microcredit initiated by the UN in 2005 and the honouring of the Grameen Bank and its founder Muhammad Yunus with the Nobel Peace Price. Studies have shown that MF has the potential to create positive impacts by overcoming financial barriers and could thus also become a promising financing mechanism for micro-energy systems. This section gives a brief introduction into MF, its development impacts and current trends in the industry.

2.4.1 Microfinance and its Development Impact

MF is linked to such great expectations as it provides access to credit for people *"living in poverty who are not considered bankable"* (Rao & Rao, 2010) by the commercial banking sector due to a lack of collateral, steady employment or a verifiable credit history. Moreover, the main understanding is that the lack of access to credit is solid ground for poverty and that microloans for entrepreneurs and small businesses are an efficient development tool reducing poverty (Demirguc-Kunt & Levine, 2008; Khawari, 2004; Schmidt, 2009). By utilizing innovative lending techniques, local information flows and consecutive loans MF overcomes informational, institutional and other

barriers that limit access to credit (Ahlin & Neville, 2008). Most importantly, social sanctions, for example through group lending and loan guarantors, information gathering from neighbours, friends or family members, and formal sanctions, such as the exclusion from future borrowing in the case of default, serve as a substitute for collateral and the lack of information about poor borrowers (Armendáriz de Aghion & Morduch, 2005; Banerjee & Duflo, 2010). With these mechanisms MF overcomes moral hazard and adverse selection and succeeds in lowering transaction costs related to loan provision and monitoring in contrast to the formal banking sector (Banerjee & Duflo, 2010; Demirguc-Kunt & Levine, 2008).

Today, over 30 developing countries have national MF strategies (CGAP, 2008) and in terms of scale, MFIs reached about 155 million clients at the end of 2007 (Daley-Harris, 2009) and the Microfinance Information Exchange (MIX) reports a gross loan portfolio of US$ 63.7 billion (MIX, 2009). Though MF is a rather young phenomenon, these numbers show that is has a respectable financial volume and outreach today (Schmidt, 2009). Even the traditional banking industry begins to provide MF services, showing that MF is *"gaining credibility in the mainstream finance industry"* (Rao & Rao, 2010).

Rapid industry development and the rhetoric about its beneficial impacts for the poor have clearly outpaced empirical evidence (Weiss & Montgomery, 2005). Economic theory predicts that the provision of access to credit increases economic efficiency and reduces poverty and inequality (Levine, 2005). But evidence that MF has macroeconomic effects is very limited and inconclusive (Karlan & Morduch, 2010). On the micro-level, identified impacts vary from poverty reduction, higher profits and growing numbers of business start-ups, increased household consumption and consumption smoothing to no or even adverse effects (Karlan & Morduch, 2010). Robinson (2001) presents examples which show that MF can have a significant beneficial impact on economic activity, household income and also on quality of life provided that credits are used for the expansion of economic activities. However, Levine (2005) points out that much more research is needed to clearly determine the impact of financial systems on development.

To put it briefly, MF alone will not eradicate poverty (Helms, 2006; Karlan & Morduch, 2010) but can support the poor in stabilizing incomes and in making future investments (Helms, 2006). The strength of MF to address imperfect credit markets combined with the outreach MFIs have today, their experience in risk management and in handling dispersed activities in poor and underdeveloped regions also summarize the main

arguments for the application of the MF approach in the rural energy sector (see also Rippey, 2009). Trends in the industry show that the range of services offered can be further extended and that building *"more inclusive financial systems"* (Kendall et al., 2010) will remain an important goal on development agendas.

2.4.2 Current Trends in the Microfinance Industry

Services of the MF industry shift evermore from the exclusive provision of microcredit for entrepreneurs to a broader range of financial services including investments in health and education, savings, money transfers and insurance acknowledging that financial needs of the poor are not limited to business loans (Armendáriz de Aghion & Morduch, 2005; Karlan & Morduch, 2010; Khawari, 2004). The process of product diversification now even turns to *"quality of life loans"* (Srinivasan, 2007) for housing and other non income-generating goods.

More recently, MFIs also started to focus on the environment, until then *"the missing bottom line"* (Hall et al., 2008) of the three-dimensional sustainability concept. An increasing number of MFIs reports their social and environmental impact[5], as responsible finance gains more importance (Rippey, 2009). Other reasons why MFIs should consider environmental assessment are the scale MF industries have reached and the related impact of served micro-enterprises on natural resources, pollution as well as occupational health, risk mitigation, proactive adaptation to sustainable development agendas of governments, and last but not least the ethical responsibility of MFIs (Hall et al., 2008; Wenner et al., 2003). The movement towards social and environmental performance is still marginal within the industry (Hall et al., 2008). But Wenner et al. (2003) point out that MFIs can and should play an important role in promoting environmental protection and in creating environmental awareness. The provision of micro-energy loans for renewables, which are further explained in the next section, are one opportunity to live up to this role.

2.5 Micro-Energy Lending

Microloans for energy systems can be seen as a continuation of the recent trend in product diversification in the MF industry (Bahnsen et al., 2009; Srinivasan, 2007). The MEL approach goes one step further than the recent development in the MF industry to

5 Sustainability guidance for MFIs is e.g. provided by FMO (2009).

consider environmental and social risks of their loan portfolio by providing products that actively address environmental problems. In the development literature are two dominant perspectives from which MEL is approached, either from a MF or from a rural electrification perspective. More recently, micro-energy loans have also been addressed in the CDM literature as a potential tool to increase the number of CDM projects in LDCs. This section presents the concept and the current status of research on micro-energy loans and outlines the implications for MEL in the international carbon market and its role in sustainable development.

2.5.1 Concept and the Current State of Research

MEL for RE or EE technologies is an approach, that simultaneously addresses the interrelated challenges of development and climate change (Aron et al., 2009; Rippey, 2009). It combines the provision of financial mechanisms adapted to the needs of the poor with access to energy and thus addresses the problem of financing, which is constantly outlined as the major barrier for access to energy (Agbemabiese, 2009; Aron et al., 2009; Beck & Martinot, 2004; Rao et al., 2009; Srinivasan, 2007). In particular, micro-energy loans address two of the barriers to rural electrification and renewable energies explained above: they overcome the market-performance barrier of the lack of access to credit for end-users and address the cost barrier of high initial up-front costs, which are prohibitive even when fuel savings justify the investment (Hosier, 2004), by spreading costs over a longer timeframe. In the literature, it is pointed out that the best approach is to adjust loan instalments to prior energy expenditure for candles, kerosene, diesel, or battery charge, which is though often not possible without additional subsidies (Martinot et al., 2001; Morris & Kirubi, 2009) indicating that MF alone will not be able to solve energy poverty on a large scale (OECD/IEA, 2010). Nevertheless, even the most expensive renewable energy source, solar PV, provides long-term cost advantages for rural populations in developing countries who usually spend a considerable amount of household income on conventional energy sources (Morris & Kirubi, 2009; REN21, 2010; UNEP, 2007a). Additional health benefits, increased safety, and less time spent in fuel collection or battery charging are further advantages driving the demand for renewable energy technologies (Legros et al., 2009; Kebir, 2007), which might also explain why the willingness-to-pay for micro-energy systems is sometimes higher than for conventional energy sources (Mondal, 2010; see also van der Vleuten et al., 2007).

But experience with MEL is still limited and further investigation on how to transfer the MF approach to end-consumer energy finance is needed (Legros et al., 2009; UNEP, 2007a). In this regard, it is important to understand that there is a clear difference between business loans, the original business of MFIs, and consumer credit provided for micro-energy systems in terms of target group, loan duration, interest rates and loan amount. In Bangladesh, for example, micro-business loans have a shorter duration, a higher interest rate and involve a smaller loan amount. Furthermore, the target group is usually poorer than that of energy loans (Martinot et al., 2001). Another integral distinction is that micro-energy loans are often non-income generating, with small shops or domestic income-generating activities being exceptions, and the return on energy-investment originates from cost savings (Srinivasan, 2007). In contrast, micro-business loans are productive and increase economic output (Karlan & Morduch, 2010). However, according to Srinivasan (2005) the distinction between productive and non-productive loans is artificial, since many micro-entrepreneurs, especially women, work out of their homes and as clean energy should be seen as an investment in health improvements and child education.

Differences between the loan schemes might also translate into different credit risks. Srinivasan (2005) points out that credit risk and timely repayment pose a serious challenge to creditors in the case of SHS dissemination due to the additional technology risk. However, loans provided by MFIs having the necessary experience in credit delivery and collection tend to reduce credit risk in comparison to credit delivery mechanisms where energy companies directly provide credit to customers (Martinot et al., 2001; UNEP, 2007a). In addition, the literature on rural electrification emphasizes that maintenance and after-sales services to customers are not only a critical factor for properly functioning energy systems but also for keeping the credit risk low (van der Vleuten et al., 2007; World Bank, 2008a).

For an MFI, the provision of energy services requires intensive capacity building, whereas energy companies have a clear expertise in this field (Morris et al., 2007). A strong partnership between energy companies and MFIs, as an alternative to an energy company offering credit or an MFI providing energy services, is thus favoured by the literature coming from both the MF (for example Morris et al., 2007) and the rural electrification perspective (World Bank, 2008a).

Though a lot of papers have investigated the relation between energy and poverty, only few papers address to role of finance, and MF in particular, in the provision of energy

access (Rao et al., 2009). Scientific literature on MEL (for example Adib et al., 2001; Srinivasan, 2007) and the literature on carbon markets (for example Hayashi et al., 2010; Rippey, 2009; Schuhmacher et al., 2009; Smuda & Karschunke, 2009; van der Gaast et al., 2009) often only point to the opportunities an integrated microfinance-energy approach offers. But only few scientific studies analyse existing MEL projects (Kebir, 2007; for example Rao et al., 2009; Urmee et al., 2009). However, some NGOs and international organizations present analyses of ongoing projects and provide valuable information on initial MFI experience with energy loans (e.g. Aron et al., 2009; Dowla, 2009; Legros et al., 2009; Morris et al., 2007). These studies indicate that MFIs have the necessary distribution infrastructure, clientele, credibility and expertise to serve dispersed rural markets and are thus potential *"key players"* (Rippey, 2009) in the dissemination of micro-energy systems. Energy loans not only create new business opportunities for MFIs but also build up mitigative capacity of developing countries (Munasinghe, 2009).

Mitigative capacity, in turn, is important to benefit from carbon revenues. And as it remains a challenge to increase the number of CDM projects in LDCs (Bahnsen et al., 2009) the combination of MF and the PoA offers potentials to achieve both financially feasible MEL activities and an increase of CDM projects in LDCs. Synergies between MF and the PoA are outlined by Bahnsen et al. (2009), who, to the best knowledge of the author, present the only detailed study of potential linkages available today. The most important synergies between the two financing mechanisms are the integration of loan and CDM monitoring procedures, the fact that both mechanisms deal with dispersed micro-activities, shared infrastructures and similar reporting procedures. The PoA can especially benefit from MF infrastructures and client networks, whereas MFIs can benefit from additional funding in order to ensure affordability (Bahnsen et al., 2009).

But although a growing number of MFIs offers energy-loans, there are only few examples that try to utilize the carbon market (Bahnsen et al., 2009) and the literature indicates that barriers to both the integration of micro- and carbon finance and MEL in general remain. The absence of rural energy networks and potential energy partners, low awareness of MFIs, energy companies and end-users of affordable renewable energy technologies as well as the need for innovative risk mitigation management impede MEL activities (Morris et al., 2007). In addition, a lack of knowledge of carbon-offset market opportunities and remaining high transaction costs of the PoA make the

integration of micro- and carbon finance difficult (Bahnsen et al., 2009). Further barriers for the use of MF in carbon-offset projects are the shorter duration of microloans in comparison to carbon crediting periods and the relatively high loan transaction costs MFIs already have (Oppermann, 2008).

In order to gain a better understanding of linkages between MF and carbon-offset project cycles as well as of remaining barriers further in-depth analyses of carbon market opportunities and real case applications are needed. Before presenting an analysis of these topics the next paragraph puts MEL in the context of the theories outlined above and derives implications relevant for the further analysis.

2.5.2 Implications from Theory and Literature for Micro-Energy Lending

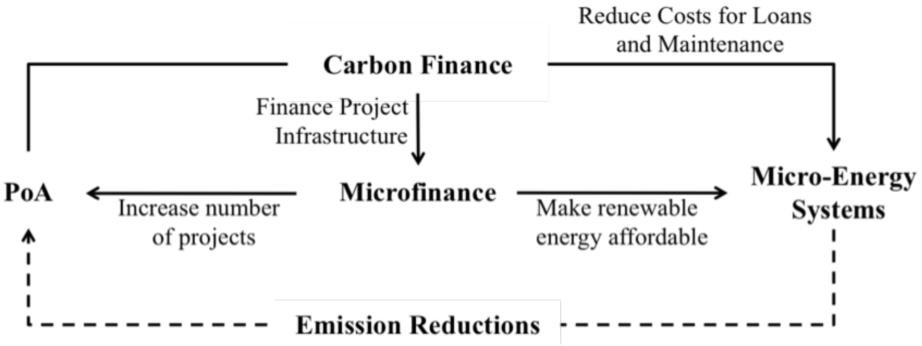
From a theoretical point of view, MEL, broadly defined in this thesis as the provision of loans by MFIs for renewable-micro-energy systems, is a promising instrument that can contribute to climate change mitigation and promote rural electrification. The approach perfectly fits into the sustainable development concept, addressing all three dimensions of the sustainable development triangle. Key linkages are the reduction of energy poverty, positive impacts of modern energy on the quality of life as well as emission reductions contributing to climate change mitigation. Though theory suggests that non-productive micro-energy loans have another impact on economic development than business loans it must be taken into account that energy is an integral input for both social and economic development. Hence, MEL can be framed as a sustainable development tool, which must be analysed and evaluated in all three dimensions.

Taking up the concept of the energy ladder, MEL for RE technologies can help the rural poor to move up the energy ladder and even accelerate the way up by leaving out rungs of the traditional energy ladder followed by industrialised countries. Emission reduction and sustainable development benefits of RE systems offer clear opportunities for MEL projects in carbon markets. In addition to the potential synergies between carbon project and MF loan cycles, the integration of energy services and MF expands infrastructure development in rural areas, intensifies strong linkages to private industries and creates ownership of electrification initiatives by beneficiaries – all factors outlined as critical to the success of rural electrification.

The integration of the two financing mechanisms, carbon finance and MF, is mutually beneficial. Carbon finance can improve the economic viability on the project level and

reduce costs for end-users, whereas MF can facilitate affordability of energy access for end-users in LDCs and increase the number of carbon-offset projects in these regions.

Figure 3: Mutual Benefits of Linking Carbon- and Microfinance



Source: Author.

In summary, MEL addresses the barrier of high up-front cost and end-consumer finance and provides opportunities to promote market-based business models. However, additional subsidies are needed in order to make micro-energy systems affordable and to provide the necessary infrastructure. Carbon finance is one opportunity to generate further financial resources but potential synergies and remaining barriers need to be further investigated. This is the focus of this thesis, which provides an in-depth analysis of MEL and its potentials in the carbon market. The methodological approach to the analysis is presented in the next section.

3 Applied Approach: Methodology and Data

As indicated in the literature review, MEL is a young approach and little data and project experience exist. Especially, the combination of the two financing mechanisms – microfinance and carbon finance – has not been discussed in detail in the literature. Prototype projects are being implemented and investigated but comprehensive data for substantial empirical analysis are not available. Accordingly, research on MEL and its potentials in the international carbon market is fundamental and this thesis is intended to add to both the theoretical framework and applied research.

The methodological approach follows a two-pronged strategy. First, a theoretical analysis of potential linkages between MEL and the pCDM as well as the remaining barriers is conducted in order to answer the first research question: What opportunities does the combination of carbon and MF offer to rural electrification and what barriers do projects face?

As the goal is to understand and describe the concept of combining micro- and carbon finance, qualitative research is conducted for this part. The strength of qualitative

research is its ability to describe a phenomenon in detail when little knowledge exists on the subject of interest (Silverman, 2006). As a source of primary data this part draws on 13 semi-structured expert interviews with carbon market, MF and rural electrification experts. Expert interviews were chosen due to the lack of both qualitative and quantitative data on the topic of interest (Silverman, 2006). Experts with experience and intensive knowledge on the market are regarded as the best source available in order to understand the potentials and barriers for MEL projects in carbon markets. The interviews include all three perspectives, microfinance, carbon finance and rural electrification, to ensure validity and generalizability of results. Questions were developed based on the initial literature review and are adapted to the background of the respective expert[6]. All interviews were recorded, transcribed and qualitative content analysis was used to identify different categories (see also Silverman, 2006) which are relevant in the context of MEL and carbon finance. By cross checking the information from expert interviews with secondary data from the literature, the analysis outlines how – in theory – MF and carbon finance can promote rural electrification and whether existing synergies are sufficient to ensure a successful combination of the two financing mechanisms.

Second, a case study of a MEL project promoting SHS in Bangladesh, which is currently in the validation phase of the pCDM, is conducted. The aim is to analyse how barriers identified in the theoretical analysis are addressed and to evaluate the performance and impact of the project. The focus is on the following topics:

(a) PoA project organization, management and monitoring (project design)
(b) Obstacles to successful CDM registration and project performance (challenges)
(c) Expected contributions of carbon revenues (economic viability)
(d) Expected and (preliminary) realized contributions to climate change mitigation and beneficial effects for the rural population (sustainable development benefits)
(e) Financial and technical performance of the project (project sustainability).

The case study adds valuable information to answering the first research question and in addition, the case study aims at answering research questions two and three: How do carbon revenues improve the economic viability of micro-energy projects and do they justify high up-front and monitoring costs? And what consequences does MEL have in

[6] A list of experts interviewed for this thesis and an overview of key questions are provided in the appendix.

respect to social and environmental benefits, i.e. does it promote sustainable rural development?

As recommended by Ilskog (2008), the case study is based on both quantitative and qualitative methods and is grounded on the following data[7]:

(a) 17 semi-structured interviews with different stakeholders including representatives from the Infrastructure Development Company Limited (IDCOL), the coordinating entity of the PoA project, from donor organizations, Partner Organizations (POs) implementing SHS in the field as well as external energy experts;

(b) Pre-defined questionnaires answered by eight SHS clients living in the Chittagong district, two micro-enterprises and six households;

(c) Internal documents, meeting minutes and correspondence between stakeholders and the author;

(d) Quantitative data from the project coordinator's database, external monitoring reports and CDM-related documentation as well as relevant literature.

Most information from the stakeholder interviews was qualitative in nature, whereas interviews with IDCOL also focused on quantitative data extracted from the project-monitoring database. The sample of SHS clients is neither expected to be representative nor random, as the POs staff attending the field visits made the choice and clients were chosen based on their proximity to each other. Nevertheless, the intention of the author was to do fieldwork in the project area, which is of great importance in the context of rural electrification projects (Ilskog, 2008), to get hands on experience in the field in order to be able to judge, cross-check and substantiate qualitative and quantitative information. But interpretation of the data has to be done with caution as the interviewees, the interviewer and the translator needed to conduct the interviews influence information (Pelto & Pelto, 1970) and the author assumes that the bias is intensified due to different cultural backgrounds.

While qualitative data gathered through stakeholder interviews serve to describe the project design and to critically analyse the project from different perspectives, quantitative data serve to conduct a multi-criteria analysis (MCA) to evaluate the ongoing project. The MCA is chosen over a cost-benefit-analysis (CBA), which is the

[7] A list of stakeholders interviewed, key questions asked to different stakeholders and the questionnaire answered by SHS-clients are presented in the appendix.

conventional framework to evaluate the impacts of projects when all effects can be valued economically, as it provides a framework to combine different forms of criteria and is not limited to monetary indicators and efficiency measures (Munasinghe, 2009; van Pelt, 1993). *"Sustainable development is multi-dimensional in its very nature"* (Nussbaumer, 2009) and as the research goal is to include environmental benefits, financial risk and technical performance indicators, which are difficult to quantify in monetary terms, MCA seems to be the perfect approach. In addition, MCA is regularly applied in a sustainable development (for example Munasinghe, 2004; Nussbaumer, 2009; van Pelt, 1993) and a rural electrification context (Cherni et al., 2007; Diego & Toshihiko, 2009; Munasinghe, 2009).

The author introduces an extension of the three sustainability dimensions including an institutional and a technology perspective. Both determine the success of the project and technology performance is key for end-consumer benefits and achieved emission reductions while institutional sustainability is crucial for a long-term existence of the project. Both dimensions play an important role in a rural electrification context and are based on the approach presented by Ilskog & Kjellström (2008) and Ilskog (2008). However, this analysis claims in no way to provide an exhaustive evaluation of the project's sustainability and its contribution to sustainable development as such. It rather allows for an evaluation of context-specific criteria for MEL projects linked to the carbon market.

As argued above the sustainability triangle extended to a technology and an institutional dimension builds the framework for the MCA, and based on sustainomics principles (Munasinghe, 2004; Munasinghe, 2009) context-specific criteria are defined for each dimension. Sustainomics requires a balanced treatment of the sustainability dimensions and strives for *"continuing improvements in the present quality of life at a lower intensity of resource use*" (Munasinghe, 2009). Indicators must represent the three sustainability dimensions, be comprehensive in scope, multidimensional in nature and reflect the development objectives (Munasinghe, 2009). To the best knowledge of the author specific indicators to assess a MEL project utilizing the carbon market have not been defined by prior studies. However, multi-criteria assessments of rural electrification and CDM projects as well as tools for MF risk assessment are used as a basis for the definition of indicators, which are presented and explained below.

Table 2: Overview of MCA Indicators Applied

Sustainability Dimension	Criterion	Indicator
Economic/Financial	• Financial Contribution of CDM	• CDM Revenue per SHS
Social	• Financial Viability of SHS for end-users	• Avoided Costs • Internal Rate of Return
Environmental	• Emission Reductions	• Change of CO2 Emissions relative to Baseline
Institutional	• MFI Credit Risk	• Portfolio at Risk
Technological	• Technical Performance of SHS	• Percentage of Deficiencies

Source: Author.

The first criterion of interest is the financial contribution of the CDM to the project, which is measured in terms of CER revenues generated during the crediting period (Satoguina, 2006). As an indicator the net present value (NPV), often applied in MCA, of the CDM contribution per SHS is calculated based on the present value (PV) of CER revenues (B) and the PV of transaction costs (C) per SHS:

$$NPV = PV(B) - PV(C) \text{ where } PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \text{ and } PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t};$$

r = discount rate, t = year, in which the cost/benefit is incurred, n = number of years.

Entering the carbon market is beneficial if the net present value per SHS is positive (compare Boardman et al., 2006) and in this case carbon finance would improve the economic viability of a project. Instead of a national viewpoint, requiring calculations with shadow prices and social discount rates, a private viewpoint is chosen as both CDM investors and MFIs make decisions based on financial viability and profitability and not on economic efficiency. Accordingly, market prices and discount rates, representing the marginal rate of return of another private investment or the cost of capital, are applied (compare Boardman et al., 2006; Munasinghe, 2009).

Two social indicators are calculated in order to define the financial viability of the SHS for end-users, the NPV taking avoided costs as the benefit and the SHS investment as the cost component and the internal rate of return (IRR) (compare with approach followed by Mondal, 2010). In the context of poor populations avoided costs are of major importance, whereas environmental reasons play a subordinate if any role in investment decisions. Accordingly, from a social perspective the financial investment to purchase a SHS, or more generally the cost of energy services to the household, is an

important social indicator (compare Meier, 2003; Munasinghe, 2009). Hence, a NPV analysis is conducted from the perspective of a household purchasing a SHS in order to learn whether the investment is beneficial from a financial point of view. As a second social indicator the IRR is calculated. The IRR is the discount rate at which the NPV equals zero and is defined as follows: $IRR = i_1 - NPV_1\left(\frac{i_2 - i_1}{NPV_2 - NPV_1}\right)$;

NPV_1 and NPV_2 for two different interest rates, i_1 and i_2, and where NPV_1 is positive and NPV_2 is negative.

It is a useful tool to evaluate an investment when there is only one alternative to the status quo, i.e. SHS as the alternative and kerosene as the status quo, and the investment in the SHS is beneficial if the IRR exceeds appropriate discount rates (compare Boardman et al., 2006; Mondal, 2010). Also for the ultimate beneficiaries of the programme, market and not shadow prices determine the attractiveness of the investment, and thus again a financial analysis is conducted.

Achievements of GHG emission reductions are the core objective of the CDM and key for sustainable energy development. GHG emission reductions are a global environmental benefit and are used as an indicator to take account of the environmental dimension (compare Munasinghe, 2009). Emission reductions are calculated based on the baseline emission (BE) scenario provided in the PoA-DD. In contrast to CBA MCA does not require converting environmental benefits into avoided damage costs and thus emission reductions are presented in tCO_2. According to the PoA-DD emission reductions per year (ER_y) are calculated based on the following formula: $ER_y = (BE_y - PE_y) - LE_y$ whereas $PE_y = 0$ and $LE_y = 0$, thus $ER_y = BE_y$;

BE_y= Baseline emissions in year y; PE_y= Project Emissions in year y; LE= Leakage emissions in year y.

In this specific case project emissions (PE) are zero as solar PV generates emissions-free electricity and leakage (LE), which would occur if other households would use the kerosene lamps and batteries replaced instead, is zero as lamps are retained by SHS customers as a back-up (IDCOL, 2010b). Thus, emission reductions are determined by the number of replaced kerosene lamps N and their respective fuel consumption FC as well as the kWh consumption of batteries charged by diesel: $ER_y = BE_y = N_y \cdot \sum_j FC_{jy} \cdot 2{,}36 + kWhC_y \cdot 0.8$ (IDCOL, 2010b);

2.36 = CO_2 emissions per litre kerosene usage; 0.8 = CO_2 emissions coefficient of diesel ($kgCO_2/kWh$).

As an indicator for the institutional sustainability the portfolio at risk (PAR), a crucial factor to assess a MEL programme, is analysed. Credit risk of MEL projects was

highlighted in the literature as the technological performance of energy systems introduces an additional risk factor in contrast to other microloans (Srinivasan, 2005; van der Vleuten et al., 2007). The PAR is a standard measure of loan portfolio quality, and is defined *"as the total outstanding balance of loans with late payments divided by the total outstanding loan portfolio"* (Robinson, 2001). In a MF context, the standard measure is PAR30, i.e. the percentage share of the portfolio, which is more than 30 days overdue (CGAP, 2008a). Unfortunately, it is not possible to get complete PAR30 data for the whole project period, as credit risk is currently measured in terms of collection efficiency (Pavel, 2010). Nevertheless, PAR30 is chosen as an indicator as it allows a direct comparison to the portfolio quality of MFIs involved in the energy-lending programme.

To assess the technical performance of the programme field inspection data from an external monitoring team are analysed and presented. Again, data do not cover the whole programme period but the number of inspections performed gives a statistically significant sample size of current installations. Technical deficiencies are divided into different categories depending on their severity and presented in simple percentages.

All indicators defined except for the credit risk and technology performance are common indicators for sustainable energy development (compare Munasinghe, 2009). Although Ilskog (2008) introduced a technical and an institutional dimension she suggested other indicators for these dimensions but at the same time points out that indicators must be *"open for enhancement, refinement, amendment and change"*. In accordance with this, the author argues that case-specificity requires an assessment of these two indicators, as a project involving MF is neither sustainable when credit risk is too high nor when the technology implemented is prone to error. Thus, in order to be comprehensive in scope the set of indicators for micro-energy projects should include these two criteria as well. Still, indicators used are not exhaustive and are open for extension. Before the case study and the MCA are conducted, the next part presents the theoretical analysis of potential linkages between MEL and the pCDM.

4 Theoretical Analysis: Linkages between Micro-Energy Lending and the programmatic CDM

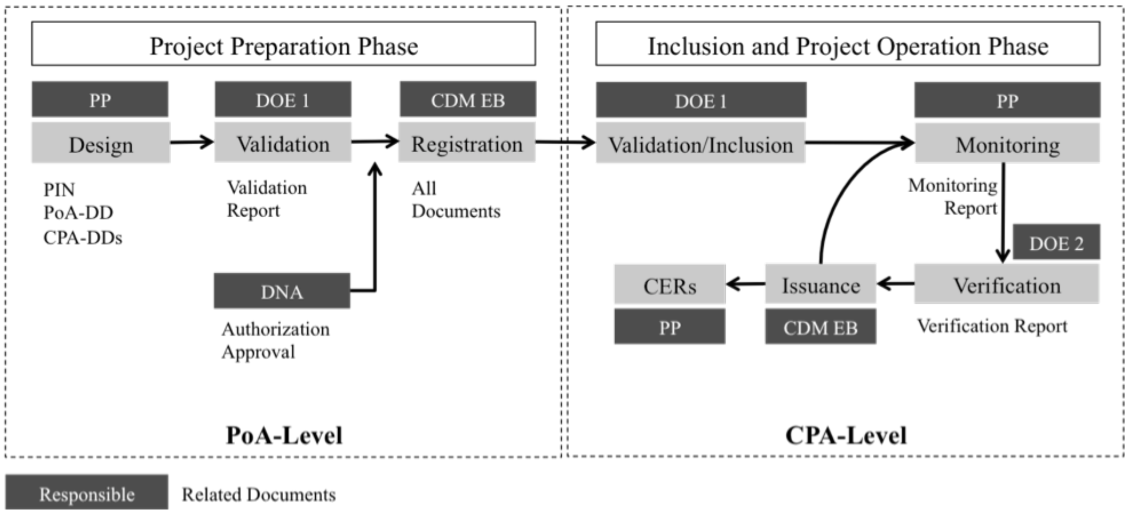
The most obvious commonalities between MFI activities and PoA projects in LDCs are the characteristics of the projects they are implementing and the client base they are serving. Both promote dispersed micro-activities and target households and SMEs in developing countries. But whether these similarities can lead to synergy effects remains to be analysed in detail, as it is amongst others recommended by the CDM EB. This section focuses on the potentials of MEL under the pCDM and the reduction of barriers to rural electrification. The synergies Bahnsen et al. (2009) identified are taken as a point of departure and information from expert interviews serve to extend the knowledge base and to identify and discuss key criteria for potential project design and business models. At the end of this section remaining barriers to MEL under the pCDM and rural electrification are outlined.

4.1 The PoA Project Cycle

The PoA is defined as a voluntary coordinated programme, which leads to additional GHG emission reductions via an unlimited number of emission reduction activities (Hayashi et al., 2010; Hinostroza et al., 2009). The most important advantage of the PoA is that CDM project activities (CPAs) can be added at any point of time during the programme duration (Hinostroza et al., 2009), which gives project developers much more flexibility, reduces transaction costs and complexity – barriers that otherwise pose a barrier for small- and micro-scale projects (Hayashi et al., 2010). Transaction costs in a CDM context are defined as the costs accruing during the CDM-project cycle, excluding costs for the operation and implementation of the programme as such[8] (Michaelowa & Jotzo, 2005). Provided the PoA achieves its goal to reduce complexity and transaction cost, this flexibility could also offer new opportunities for MFIs providing micro-energy loans as suggested in the literature. As a basis for the analysis how the two financing mechanisms can be combined the PoA project cycle and the parties involved are outlined in the figure below and explained in the following.

[8] An overview of CDM transaction costs is provided in the appendix.

Figure 4: The PoA Project Cycle



Source: Author. Note: Parties not explicitly outlined in the graph are external consultants and the CER buyer. Both can but do not have to be involved in CDM projects, though consultants are usually involved in projects in LDCs.

In contrast to stand-alone CDM projects a PoA project is managed on two levels, the programme (PoA) level and the programme activity (CPA) level. The programme level, managed by the coordinating entity, provides the necessary *"organizational, financial and methodological framework"* (Hayashi et al., 2010) while actual emission reductions are achieved on the CPA level.

The Project Preparation Phase comprises the project design, validation and registration and involves different CDM-related bodies. The most important project participant (PP)[9] is the coordinating or managing entity, which initiates, organizes and implements the programme and which is thus also responsible to prepare the documents relevant for registration, i.e. the CDM Programme of Activities Design Document (CDM-PoA-DD) and the CDM Programme Activity Design Document (CDM-CPA-DD)[10] (IGES, 2010). Most importantly these documents have to provide relevant information on the applied baseline and methodology(ies), on programme duration, monitoring procedures and eligibility criteria for the inclusion of additional CPAs, demonstrate additionality on PoA and CPA level, calculate expected emission reductions and outline the environmental and social impact of the programme (Bahnsen et al., 2009). During the Project Preparation Phase the coordinating entity must obtain a letter of authorization from the Designated National Authority (DNA) of the host country allowing the entity

9 The coordinating entity is required to be a PoA project participant, contrary to CPA owners or other stakeholders.

10 One generic CDM-CPA-DD and a specific CDM-CPA-DD for the first CPA implemented must be prepared for registration. An additional Programme Idea Note (PIN) is voluntary but a good basis for feasibility studies.

to coordinate the programme and a letter of approval from the DNAs of all parties involved, i.e. the host party and potentially Annex I countries, approving the programme as such. The programme documentation has to undergo external validation by an accredited Designated Operational Entity (DOE), which submits a final validation report to the CDM EB for registration (Bahnsen et al., 2009; Hinostroza et al., 2009).

It is important to mention that project documentation and the process until registration is very complex and time-consuming. On average it takes 482 days or 16 months (author's calculations based on UNEP Risoe Centre, 2010) for CDM projects from the start of the commenting period – before validation documents are made publically available for comments – to registration. This timeframe does even not include preparation time for the PoA-DD.

Emission reductions and carbon revenues are generated in the Inclusion and Project Operation Phase. The crediting period for a specific CPA can be either a maximum of 10 years or 7 years with the possibility to renew the crediting period twice. All CPAs must end with the PoA, which can have a maximum duration of 28 years (Hinostroza et al., 2009). The advantage of the PoA is that the CDM EB is not involved in additional CPA inclusions (Marr, 2010). Thus, the registered PoA reduces the regulatory risk for associated CPAs significantly and makes it easier for further PPs to join the programme as the coordinating entity provides a validated CPA concept. Other PPs do not have to handle the excessive CDM documentation, validation and registration, as the DOE adds eligible CPAs after validation (Hinostroza et al., 2009). The main task of the coordinating entity in the Project Operation Phase is the monitoring of all CPAs according to the monitoring plan presented in the PoA-DD and to summarize results in monitoring reports (Bahnsen et al., 2009). Based on the monitoring reports verification of emission reductions is conducted by a second DOE, which is not involved in the validation and inclusion of CPAs. The respective DOE requests CER issuance by submitting a certification report, confirming that real, measurable and additional emission reductions have been achieved, to the CDM EB, which in turn issues CERs provided that no review is requested (Bahnsen et al., 2009).

The whole project cycle from the start of the commenting period to the first issuance of CERs and thus the first time when the project actually benefits from carbon revenues takes, on average, 934 days or 31 months (UNEP Risoe Centre, 2010).

The relevant question now is how MFIs can be involved in the complex PoA process, to utilize the carbon market efficiently and to link the two financing mechanisms in order to overcome barriers to rural electrification.

4.2 Combining Micro-Energy Lending and the PoA

In short, there are three main contributions of MFIs according to Bahnsen et al. (2009): MFIs offer a well-established client network in rural off-grid areas, access to credit for end-users, which can be extended to energy loans, and experience in administration, implementation and monitoring of dispersed programmes. MF and carbon market experts in general confirm these strengths of MFIs, which are discussed in detail in the following paragraphs. The main contribution of the pCDM is the financial return, which could enhance credits and provide upfront finance (2009). In addition, MFIs get an attractive opportunity for product diversification through the pCDM (Hayashi et al., 2010) by converting environmental benefits created by RE or EE technology dissemination into financial cash flows (Steidl, 2010).

4.2.1 Microfinance Infrastructure

The regulatory framework offered by the pCDM is not enough to implement carbon projects. What is needed is an infrastructure to disseminate RE technologies and to reach scale in a relatively short period (Bahnsen, 2010). Experts agree that it is an opportunity to overcome the lack of infrastructure by utilizing existing MF infrastructure and their well-established client network (Bahnsen, 2010; Hodes, 2010; Marr, 2010; Neufeld, 2010; Ruelle, 2010). For carbon project developers it is extremely difficult to get on the micro-household level in rural areas, but this is where emission reduction potentials in LDCs are and where MFIs operate. In addition, it would be a waste of resources to duplicate the existing infrastructure (Bahnsen, 2010). MFIs can thus serve as a gateway providing an infrastructure in place and thus enable the dissemination of technologies (Bahnsen, 2010; Stehr, 2010; Steidl, 2010).

Furthermore, MFIs clearly have experience with dispersed loan programmes and they possess knowledge on client needs, the markets and geographical areas in which they operate (Marr, 2010; Stehr, 2010). This knowledge and experience can not only facilitate programme operation but also project design as access to a client network for stakeholder consultation and market surveys is provided and knowledge on the barriers the clients face is at hand.

4.2.2 Monitoring

Monitoring procedures needed for loan and carbon emissions tracking are identified as the most important synergy between the two financing mechanisms by Bahnsen et al. (2009). Estimated costs for monitoring are in the range between EUR 30,000 – EUR 100,000 depending on project type and methodology (Hayashi et al., 2010) and thus account for the largest portion of costs in the operational phase. Though sampling often is allowed in the case of dispersed micro-activities using a small-scale methodology accurate monitoring, which is of major importance for both environmental integrity and carbon revenue generation, is a critical matter in the Project Operation Phase (Marr, 2010).

The complexity of monitoring depends on the technology applied. For renewable energy systems, such as solar, monitoring is not too complex and can be linked with existing loan monitoring procedures provided staff is trained adequately (Arens, 2010; Ruelle, 2010). Most importantly it has to be checked whether systems are well-functioning and used regularly (Sanford, 2010). Loan repayment serves as one indicator for a regular use of the system and some methodologies even allow evidence of repayment as a substitute for on-site check-ups (UNFCCC, 2010e). An alternative is that loan officers collecting repayments in the field combine collection and systems checks effectively.

Another crucial point driving monitoring costs per unit is geography and dispersion of energy systems (Bahnsen, 2010). This is exactly why the utilization of MF infrastructure in rural areas for carbon monitoring is attractive: building on an existing monitoring infrastructure can reduce unit costs significantly and contribute to the financial viability of a programme (see also Bahnsen, 2010). Of course, an important criterion in this context is outreach of the MFIs involved and proximity of branch offices to potential energy clients. The higher the market penetration of MFIs the lower the cost of monitoring.

Nevertheless, the challenge of cost-efficient monitoring for the whole duration of the crediting period should not be underestimated (Bahnsen, 2010; Neufeld, 2010; Steidl, 2010; Wiese, 2010). Data have to be gathered, stored and identifiable for every single system installed (Neufeld, 2010; Sanford, 2010). Databases have to be adjusted or developed from scratch in order to fit both loan monitoring as well as CDM monitoring requirements and organizational processes must be adapted to monitoring procedures exceeding repayment periods (see also Neufeld, 2010; Sanford, 2010). Accordingly,

MEL and carbon monitoring require higher administrative efforts than other loan products ending with repayment and therefore, successful energy lending also depends on the mission and commitment of the MFI – just for the sake of product diversification energy products are too complex (Steidl, 2010). Breaking energy-poverty must become part of the MFI's mission in order to successfully promote RE technologies (Sanford, 2010). It thus can be inferred that carbon revenues must be in the range of covering or exceeding additional administration costs to offer an incentive to involve in MEL.

Another disparity in carbon and loan monitoring is the different duration of loan and carbon project cycles. MF loan-cycles are by nature shorter than crediting periods in carbon markets. Seven- or ten-year CDM crediting periods are contrasted with loan cycles that are rarely longer than 3 years for micro-energy systems such as SHS and this already exceeds micro-credit periods that are often shorter than a year. While loan repayment is a very good indicator for a functioning energy system – once technical problems occur clients usually stop repayment – monitoring after repayment requires additional cost and effort (Bahnsen, 2010; Stehr, 2010; Steidl, 2010). There are two alternatives that must be evaluated on a case-by-case basis. Either carbon crediting is limited to the repayment period, which would guarantee accurate monitoring and a complete overlap of loan and carbon monitoring. Aligning loan and monitoring cycles is the simple approach but this might not be reasonable for micro-energy systems[11] with much longer life-times (Bahnsen, 2010). Limited crediting periods curbs carbon revenue depending on the lifetime of the energy system. SHS, for example, have a lifetime of more than 20 years and limiting the crediting period to only 3 years would reduce the number of credits significantly. Nevertheless, key for successful PoAs is volume and in specific cases it can proof to be more interesting to add further CPAs than extending the lifetime of existing projects (Bahnsen, 2010).

The second approach obviously is to aim for longer crediting periods and cover additional expenses for monitoring by carbon revenues. A relationship between the MFI and the client beyond the loan period can be either established by maintenance contracts after loan repayment, incentive schemes, such as carbon revenue share or price reductions, or additional loan products ensuring a relationship to the client (Neufeld, 2010). But even without additional arrangements the close relationship between the loan

[11] For energy efficiency measures, such as cook stoves loan and crediting periods are easier to align due to short life-cycles of one or two years and lower up-front costs (Bahnsen, 2010).

officer and the energy client can be sufficient to provide access to households for monitoring throughout the crediting period (Sanford, 2010). Under this approach securing access to the client but also establishing an incentive scheme for MFIs[12] to monitor is needed. On the MFI-level carbon revenue share based on monitoring activities and issued CERs is the best solution (Sanford, 2010). However, CDM revenues are rather small per micro-energy system and thus accurate monitoring according to CDM rules is often not priority (Marr, 2010). Furthermore, it has to be taken into account that, in contrast to other loan products of MFIs, the loan cycle is completed while the carbon credit cycle is not, which requires changes of organizational structures within MFIs.

An additional challenge for monitoring is the dependence on user behaviour, which can undermine emission reductions (Bahnsen, 2010; Sanford, 2010; Wiese, 2010). In the case of SHS, for example, it is important to track user behaviour when it comes to battery replacement or technical failures after the loan is fully repaid (see also Bahnsen, 2010), because continuous use of the system is key in order to claim CERs according to baseline calculations. Again, a great advantage when an MFI is involved is the close client relationship, which facilitates client education on technology use and maintenance (Sanford, 2010). This is also a clear advantage over other potential project participants such as NGOs, public agencies or technology providers. Alternatively, a maintenance contract can reduce the risk of non-reported technical failures.

In summery, the MFI monitoring infrastructure in place, the existing client relationship and the fact that loan repayment is a good indicator for well-functioning and used energy systems facilitates PoA implementation and can reduce transaction costs significantly. However, carbon monitoring requires a sophisticated database, changes organizational procedures within MFIs and requires additional human and financial resources, which generated carbon revenues must be able to cover.

4.2.3 Choice of Coordinating Entity

Whether an MFI should be the co-ordinating entity or only implement GHG reductions must be evaluated on a case-by-case basis. What is of major importance is that the coordinating entity has the *"managerial capacity and the staying power"* (Bahnsen et al., 2009) to promote, implement and supervise all CPAs throughout the whole

[12] When the MFI is the coordinating entity of the programme the motivation to monitor is not questioned.

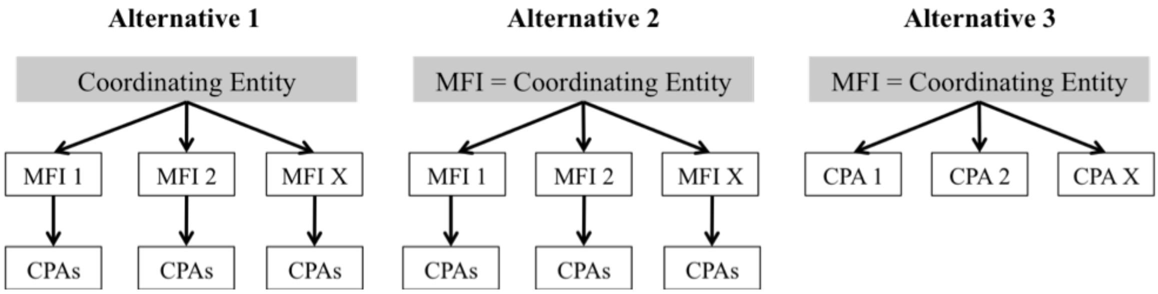
programme period. The coordinating entity not only has to design the programme and prepare CDM documentation, all of which can be outsourced to external consultants, but also has the responsibility to communicate with the CDM EB, coordinate financial flows and monitor the CPAs (Hayashi et al., 2010; Hinostroza et al., 2009).

Consequently, the coordinating entity must have a very good understanding of the CDM process, the required technical qualifications for installation and maintenance and must be able to establish very good communication flows with all project participants (Arens, 2010; Bahnsen, 2010; Ruelle, 2010). Next to public agencies, private organizations such as NGOs or utilities, MFIs or other financial institutions are potential PoA coordinators. Their particular strengths compared to the other organizations are their outreach to target groups, their ability to manage financial flows and monitoring systems (Neufeld, 2010a; Neufeld, 2010). Furthermore, established MFIs are bankable (Marr, 2010; Neufeld, 2010) – an important argument as the low overhead of MFIs makes pre-financing of micro-energy programmes or CDM transaction costs difficult (Sanford, 2010). In contrast to public agencies, which can have extremely bureaucratic structures and reconciliation procedures, MFIs are usually very efficient and fast (Neufeld, 2010; Sanford, 2010).

Certainly, when the infrastructure in place is outlined as an argument to involve MFIs in carbon projects, it is also an argument for MFIs to function as a coordinating entity. They have the experience on the ground (Bahnsen, 2010) and their infrastructure is the basis for efficient monitoring and that in particular is one of the most important tasks of the coordinating entity (Neufeld, 2010). Additionally, their access to and knowledge on target groups allows them to promote programmes adequately in rural areas and thus to overcome lack of information on RE opportunities (Neufeld, 2010).

Another key characteristic of a coordinating entity outlined in the literature (Hayashi et al., 2010) and confirmed by carbon market experts is that operations of the coordinating entity should cover the geographical boundary of the PoA or ensure total coverage through partnerships (Arens, 2010; Bahnsen, 2010). This relates to the size of the MFI. An MFI should have a relevant number of potential energy clients to be able to benefit from product diversification in energy lending and involvement in the carbon market (Sanford, 2010) but also to function as a coordinating entity. Both, outreach and size also bring collaboration between or a network of MFIs into discussion. Alternative set-ups involving MFIs are shown in the figure below.

Figure 5: Alternative Organizational Set-ups



Source: Author.

Small MFIs in any case are dependent on a coordinating entity that initiates a PoA, is able to bundle a number of CPA owners and to extend the programme over time in order to reach scale (see also Ruelle, 2010). This is shown in alternative 1 and 2. In the first case, an NGO or public agency coordinates the programme and MFIs function as CPA implementers, whereas in the second case an MFI functions as the coordinating entity. In contrast, only MFIs having a significant size, geographic outreach and client base might be able to reach relevant numbers of micro-energy projects making a PoA feasible. This situation is shown in alternative 3. In most cases, it seems to be more promising to initiate a PoA that bundles activities of a number of MFIs operating in different regions. As the scale of a PoA determines the financial contribution of carbon revenues even cross-border PoAs might come into consideration. As an example, Improved Cook Stoves for East Africa (ICSEA) is a PoA currently in validation covering several countries in the East African region (UNFCCC, 2010c). This might also be an opportunity for RE technologies such as SHS in order to promote rural electrification and to keep CDM transactions costs as low as possible.

It should be clear, that even when MFIs are only involved in a PoA as CPA implementers the coordinating entity can still benefit from the MF infrastructure. Though monitoring must be done by the coordinating entity, MFIs can provide access to households and carbon revenue shares can function as an incentive for MFIs to support monitoring activities.

Keeping all the advantageous characteristics of MFIs in mind, as a point of departure, MFIs lack knowledge on the carbon market. Additional capacity building on the CDM is required (Stehr, 2010) to overcome the information barrier on carbon market opportunities (Ruelle, 2010) and to ensure that the respective MFI has the capacity to manage a PoA. This also includes additional human and financial resources required for coordination, which otherwise pose a barrier for MFIs to enter the carbon market

(Sanford, 2010). Carbon revenues generated must be able to cover additional costs. As a consequence, MFIs should be targeted by capacity building initiatives organized by international carbon funds and an exchange of experience between MFIs involved in carbon market activities should be supported on an international scale (see also Arens, 2010).

A further drawback for both, monitoring and PoA coordination, is that most MFIs have no technical expertise, which might require partnerships with energy or technology providers (Bahnsen, 2010; Marr, 2010; Wiese, 2010). The literature indicated that a partnership between a MFI and an energy or technology provider is the preferred approach as MFIs lack the technological capacity for installation, maintenance and monitoring and energy providers lack the experience in credit administration. While this is confirmed by MF experts (for example Steidl, 2010) carbon market experts point out that a reduction of the number of the parties involved reduces transaction costs (Bahnsen et al., 2009; Bahnsen, 2010; Stehr, 2010). From a cost perspective and following classic transaction cost theory, stating that integration reduces the cost of negotiation and contracting (Coase, 1937), an integration of all different tasks – CDM coordination, loan and carbon monitoring and technological maintenance – is the preferable approach. Furthermore, it should be taken into account that, in contrast to MFIs operating in rural areas, energy utilities do usually not have distribution networks in rural areas and often exclusively promote grid-extension disregarding remote areas that do not prove to be financially viable (World Bank, 2008). Training of MFI loan officers or hiring of technical experts is thus regarded as the preferable option instead of replicating existing infrastructure.

4.2.4 Incentive Schemes and Use of Carbon Revenue

In the context of a PoA, incentive schemes aim at inciting emission reductions by making the respective technology promoted under the programme attractive to target groups (Bahnsen et al., 2009; Hayashi et al., 2010). The right incentive scheme is key for successful implementation and determines the scale of the programme (Marr, 2010). In order to design an incentive scheme, knowledge on the needs and barriers end-users of the micro-energy systems face are required (Hayashi et al., 2010; Neufeld, 2010), which is a further strength of MFIs (Neufeld, 2010).

The idea of the PoA is to finance incentive structures with carbon revenues generated under the programme. Involving MFIs can create a need for incentives on two levels,

the end-user level and the MFI level to incite energy loan products. Potential economic incentives on both levels are presented in the table below.

Table 3: Economic Incentives for End-Users and MFIs

Incentives for end-users
Grant Programme: Upfront grant payment or price reductions
Loan Programme: Reduction of interest rates
Supply Programme: Price discounts or free distribution
Payment on Delivery: Revenue share when CERs are issued
Incentives for MFIs
Grant or Payment on Delivery for Institutional Development and Staff Training
Grant or Payment on Delivery to finance an extension of the energy-loan programme
Grant or Payment on Delivery to finance maintenance and after-sales services
Unconditioned Payment on Delivery

Source: Author based on information from Neufeld (2010), Sanford (2010) and Hayashi et al. (2010).

In the case of SHS grant and supply programmes are most relevant in order to overcome the barrier of high up-front costs for end-users. When MFIs are functioning as a coordinating entity, carbon revenues of course also have to cover CDM transaction costs. A coordinating entity contracting MFIs can condition the use of carbon revenues on particular purposes and provide payments as a grant or on delivery depending on the needs of the MFI.

4.2.5 Project Types and Scale

Most likely carbon projects implemented in combination with MF are small-scale activities. In the case of the PoA not the entire programme but the individual CPAs have to be small-scale, where the threshold is defined as a maximum output capacity of 15 MW in the case of RE (Type I) project activities (Hinostroza et al., 2009; IGES, 2010). Analysing the PoA pipeline clearly shows that the vast majority of projects applies small-scale methodologies (UNEP Risoe Centre, 2010), indicating that the PoA especially promotes micro- and small-scale projects and thus has the potential to fulfil its initial goal of including dispersed small-scale activities.

In addition, MEL projects are characterised by single or several measures applied at many locations[13]. The fact that a combination of different methodologies requires

[13] Alternatives are the application of a single measure or several measures at a single location.

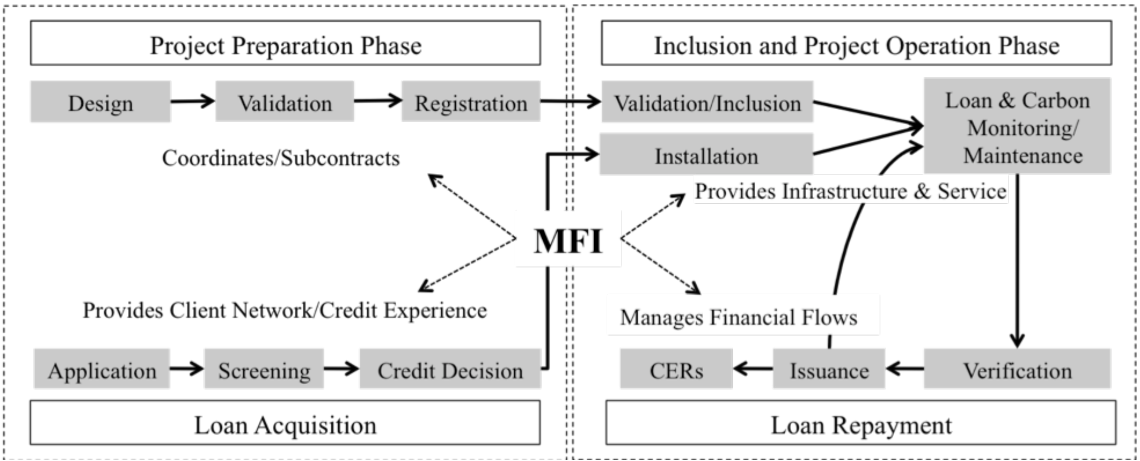
approval of the CDM EB and that all CPAs have to be identical (Hinostroza et al., 2009) makes single measures, such as the application of SHS[14], most likely.

In regards to project scale, numbers referred to by experts vary from 60,000 to 150,000 tCO_2/year for mature PoAs and maturity or break-even should be reached after 3 – 4 years (Neufeld, 2010; Ruelle, 2010). Small-scale PoAs might also be as small as 50,000 tCO_2/year (Ruelle, 2010). These numbers refer to average emission reductions over the whole crediting period and are very likely to be much lower during upscaling of the programme (Neufeld, 2010). Key for carbon revenue generation under the PoA is a fast expansion of the programme (Bahnsen, 2010) and as pointed out above, MF infrastructure can facilitate fast dissemination.

4.2.6 An Integrated Micro-Energy Lending Carbon Project Cycle

Starting from the PoA project cycle and the analysis above an integrated cycle linking carbon and microfinance is outlined in the figure below.

Figure 6: Integrated Project Cycle Combining Carbon and Microfinance



Source: Author. Note: This project cycle is based on the assumption that the MFI functions as the coordinating entity and provides technical services either by trained loan officers or a technical department.

While the Project Preparation and the Loan Acquisition Phase proceed independently from each other (and do not have to run parallel) the Project Operation and Loan Repayment Phase yield linkages resulting in an integration of the two cycles. These linkages are determinative for a successful combination of the two financing mechanisms and thus for reductions of transaction costs and CDM-related barriers. Key

[14] Further technologies for rural off-grid areas are presented in the appendix.

is loan and carbon monitoring, which can be integrated with maintenance services after loan repayment.

Two steps in the project cycle, screening and maintenance, which were not discussed before are crucial for credit risk. First, the fundamental difference between microloans and energy loans, i.e. income-generation and no income-generation, does not necessarily enhance credit risk (Steidl, 2010). Programmes should be designed in a way that energy savings equal loan expenditures (Wiese, 2010) so that cost avoidance instead of revenue generation provides financial resources for loan repayment. However, risk assessment and borrower screening, which is at the core of the MF business (Neufeld, 2010), have to be done with scrutiny and ensure repayment capacity. Especially in rural areas, where incomes often fluctuate assessment of financial solvency is imperative and MFIs must have a clear idea on prior energy expenditures of micro-energy customers. On the other hand, with energy-loans MFIs have a much better control over the actual investment of the loan, as the loan cannot be diverted to any unintended investments (Steidl, 2010). In turn, technical performance and potential technical errors introduce an additional credit risk, as client dissatisfaction will result in refusal of loan repayment making well-established maintenance and after-sales services a critical success factor (Steidl, 2010). This is in line with the argumentation presented in the literature (Srinivasan, 2005; van der Vleuten et al., 2007; World Bank, 2008a).

4.3 Remaining CDM-related Barriers

The major barriers for small-scale projects outlined in the literature are transaction costs and complexity of the CDM (Bahnsen et al., 2009; Chaurey & Kandpal, 2009; Hayashi et al., 2010). Although the goal of the pCDM was to address these two barriers in particular, they remain the most important barriers for micro- and small-scale projects (Bahnsen, 2010; Marr, 2010; Ruelle, 2010; Stehr, 2010; Sterk, 2010). However, compared to stand-alone CDM projects PoA regulation lowers cost and complexity barriers (Marr, 2010; Neufeld, 2010). As fixed costs constitute the largest share of transactions costs (Michaelowa & Jotzo, 2005), achieved volume of the programme, i.e. the number of CPAs added over time, is decisive for the spread of initial investment and thus for cost reductions per micro-energy system (Bahnsen, 2010; Neufeld, 2010). But due to long project periods the final size of the programme is uncertain (Bahnsen, 2010) and initial investment for PoAs can even exceed investments for stand-alone projects (Neufeld, 2010).

However, overcoming the cost barrier by upscaling is much easier than to overcome complexity (Neufeld, 2010). The know-how required for the whole documentation and registration process often make external consultants indispensable, as there is a lack of capacity on the local level (Marr, 2010; Neufeld, 2010; see also Ruelle, 2010; Stehr, 2010). Involving another party increases transaction costs and indicates that next to simplifications capacity building is of major importance for LDCs. On the CPA-level complexity is certainly reduced as the PoA provides the right framework and as not every micro-energy system has to go through the complex CDM process (Marr, 2010). Accordingly, transaction costs and complexity remain barriers to entry on the PoA level, but once a PoA is registered barriers for further CPAs are reduced significantly.

Interesting in this regard is, if linking MF with PoA activities can further help to overcome barriers. As indicated in the discussion above the involvement of MFIs can reduce transaction costs in the project design phase by providing knowledge of and access to potential clients for stakeholder consultations or feasibility studies, and the design of incentive schemes. In the project operation phase, monitoring costs can be reduced significantly. But the very problem when combining MF and carbon finance is that revenue streams are not well matched (Stehr, 2010). While the CDM generates carbon revenues after project implementation and a certain period of operation (World Bank, 2008a), MFIs need investment up-front, first of all to cover CDM transaction costs but also to purchase energy units, to provide an energy loan or to create an incentive-scheme in order to initiate a programme. Though the CDM was designed as a co-financing mechanism it does not provide the necessary seed funding to implement emission reduction projects and this poses another major barrier (Arens, 2010; Bahnsen, 2010; Marr, 2010; Neufeld, 2010; Ruelle, 2010; Sanford, 2010; Stehr, 2010; Sterk, 2010). Consequently, a mechanism is needed to capitalize carbon revenues before project implementation (Hayashi et al., 2010; Stehr, 2010). A possibility for the project owner is to enter an Emission Reduction Purchase Agreement (ERPA) with an investor willing to provide upfront-payment[15] (Hayashi et al., 2010). But the willingness of investors, especially of private investors, to enter an ERPA without clear regulations for the post-2012 period[16] (Arens, 2010; Ruelle, 2010) paired with extremely long

[15] The World Bank provides up to 25% of the ERPA value up-front and undiscounted (World Bank, 2010). Other sources refer to upfront payments of 10 – 20% of nominal ERPA value (Kossoy & Ambrosi, 2010).

[16] The European Trading System (EU ETS) guarantees demand for CERs from LDCs even after 2012 (EU, 2009). For a detailed discussion refer to the appendix.

registration periods and insecure certificate delivery (Neufeld, 2010) is rather limited. Moreover, the CDM market was strongly affected by the economic crises and increasing risk aversion of project investors and offset buyers reduced the number of up-front payments (Kossoy & Ambrosi, 2010). Another drawback is the potential loss of revenue, as granting money based on future carbon revenues is associated with low CER prices to account for the risk of insecure certificate delivery (Stehr, 2010). However, being an MFI that can proof some institutional continuity and a reliable track record reduces the risk for the CER buyer and in turn increases chances to get upfront finance (Marr, 2010; Stehr, 2010). What has to be taken into account is that ERPAs usually only cover CDM transaction costs but do not grant seed financing for programme initiation, such as purchasing energy systems or creating incentive schemes (Neufeld, 2010). To close this financial gap additional loans are needed and again experienced MFIs strengthen confidence in a programme due to their experience in dispersed micro-activities. Accordingly, involving a MFI could ease the challenge to get up-front finance to cover transaction costs and seed funding for the initiation of a carbon project. In turn, it might be easier for MFIs to enter the carbon market than for other potential coordinators or project owners.

Until now unilateral PoAs with private investors are scarce and in most cases donors are the driving force behind pCDM projects and finance project design and documentation (Bahnsen, 2010; Neufeld, 2010). The scarcity of finance also highlights that funds for LDCs and micro-scale projects with high development co-benefits are urgently needed (Sanford, 2010). To address the up-front cost barrier and the unequal distribution of CDM projects, a loan scheme to promote the development of CDM projects in countries having less than 10 CDM projects was adopted recently at the COP16 in Cancun (UNFCCC, 2010h). This certainly is a step in the right direction that can greatly reduce up-front cost barriers of the CDM.

One measure currently under discussion to reduce complexity and thus also transaction costs is standardization (Bahnsen, 2010; Marr, 2010; Stehr, 2010; Sterk, 2010). Certainly, in order to ensure environmental integrity an offsetting mechanism must fulfil certain standards and procedures but when the explicit goal is to include LDCs and emission reduction potentials on the demand-side standardizations are one option to ease utilization of the CDM (Bahnsen, 2010; Marr, 2010; Stehr, 2010). In addition, standardization serves the goal of higher objectivity in baseline calculations (Sterk, 2010). A particular example is the standardization of baselines by allowing the use of

standard values for kerosene replacement by SHS circumventing cost-intensive baseline surveys on kerosene consumption. Standard values could build on experience from other regions with comparable energy patterns (Marr, 2010a). The challenge here is to introduce standard values without putting environmental integrity and additionality at risk, i.e. standard values must be conservative and ensure that calculated baselines do not exceed actual emission reductions (Arens, 2010; Bahnsen, 2010; Marr, 2010). Marr (2010) points out that optimization of methodologies would make it much easier to apply PoAs, especially because methodologies used under the PoA have not been used regularly for stand-alone CDM projects. But again, the challenge is to strike a balance between simplification and environmental integrity (Arens, 2010).

A first regulation simplifying the rules for very small-scale projects (VSSC) is that additionality for VSSCs can be established based on simple yes/no criteria (see appendix) provided that the project is implemented in a LDC, a small-island development state (SIDS) or in other underdeveloped regions, that the project is implemented on the household or SME level and that market penetration of the respected technology is below 5%. Furthermore, RE projects should only be in off-grid areas and not exceed 5 MW of installed capacity (Arens, 2010a). Another concession in the CDM set of rules is that LDCs are exempted from registration fees and administration share of proceeds (CDM Rulebook, 2010b).

Another risk for project developers and owners is the inefficiency of the CDM market (Kossoy & Ambrosi, 2010). Carbon experts confirm that the duration and time lag of the registration process is a serious problem (Ruelle, 2010; Sterk, 2010). The process can take longer than the actual implementation of a project resulting in lost carbon revenues (Ruelle, 2010). This is especially a problem, as CERs cannot be issued retroactively (CDM Rulebook, 2010) and as cash-flows are strongly needed in early project phases. Sanford (2010) points out that for micro-scale projects the combination of high up-front costs and the time lag of revenue generation is the most important barrier to entry. MFIs usually operate with very low overhead and little excess capacity are thus dependent on fast revenue generation (Sanford, 2010). Compared to stand-alone CDM projects, inexperience with the PoA as a new instrument (Marr, 2010) and rules, which are still under construction (Arens, 2010) even increase time lags and also account for the small number of PoAs registered. In addition, DOEs are reluctant to validate PoA projects (Arens, 2010; Marr, 2010; Ruelle, 2010) due to a specific regulation, which states that DOEs are financially liable for the CER value generated by

erroneously integrated CPAs[17] (Arens, 2010b), resulting in long negotiation and contracting periods with DOEs (Neufeld, 2010).

Though the PoA introduces much more flexibility to the CDM compared to stand-alone CDM projects, for a 28-years programme period the level of specificity that has to be provided when registering the programme is still very high (Ruelle, 2010). As an example, all CPAs have to apply identical measures and have to be consistent throughout the whole programme period (CDM Rulebook, 2010a). A MFI could for example not promote SHS and energy efficient cook stoves under the same PoA. Allowing multi-technology programmes could increase the flexibility even further and allow PoAs to reach scale much faster (Ruelle, 2010). On the other hand, a certain focus and feasibility of technology combinations should be maintained to ensure operability (Bahnsen, 2010). But to target the barrier of transaction costs multi-technology programmes would address this issue, as a combination of different technologies under one PoA would clearly reduce costs. What must be ensured is that the PoA-DD comprises eligibility criteria for every potential CPA making the documentation more complex in the first place.

In summary, CDM-related barriers for micro-energy projects are high upfront costs and complexity, long duration of project development and registration as well as difficulties to get seed funding. Carbon experts, however, agree that the PoA has the potential to increase dispersed micro- and small-scale projects and that can already be seen in the pipeline (Arens, 2010; Marr, 2010; Neufeld, 2010). Linking micro-energy lending and carbon projects can reduce CDM transaction costs and the experience of MFIs in rural areas as well as their extensive client network might facilitate access to the carbon market. Of major importance is to overcome the lack of information and capacity building to utilize potential synergies and benefits.

4.4 Remaining Barriers for Rural Electrification

The question of major importance is whether MEL combined with carbon finance can remove barriers to rural electrification. Financing certainly is the major barrier to rural electrification and renewable energy, which is indicated in the literature and confirmed by experts working in the field (Bahnsen, 2010; Drenkard, 2010; Gomez, 2010; Wiese, 2010). High up-front costs are not affordable for end-users and in contrast to grid-

[17] CPAs that do not comply with the eligibility criteria outlined in the PoA-DD (Arens, 2010b).

electricity which is usually subsidized in developing countries, e.g. in the form of social tariffs, subsidy and other financial mechanisms making electricity accessible for end-users in rural off-grid areas are often missing (Wiese, 2010). Microfinance can overcome *"liquidity constraints of micro-entrepreneurs and low-income households"* (Steidl, 2010) and ensure affordability of energy systems by apportioning the costs over a longer period. Accordingly, it overcomes the market performance barrier of the lack of access to credit, but both energy loans and microfinance, especially individual loans, do not target the poorest of the poor (Steidl, 2010; Wiese, 2010). For them, micro-energy systems are still not affordable. Moreover, credit is not sufficient to overcome the cost barrier. Additional grants are needed to ensure affordability (Wiese, 2010), which is partly due to legal and regulatory barriers, such as subsidies for fossil fuels, preventing a level playing field between renewable and conventional energy sources (Beck & Martinot, 2004; Wiese, 2010; World Bank, 2008). Carbon revenues as an additional financial source are thus urgently needed but current price levels do not fill the gap and high CDM transaction costs further diminish potential revenue streams. Carbon revenues only contribute a fraction of high investment costs and can thus not overcome upfront cost barriers (Bahnsen, 2010; Drenkard, 2010; Wiese, 2010). For now, it seems as if barriers prevent the PoA to take off for rural electrification. If a project is not financially viable it will not get viable with the carbon market (Drenkard, 2010).

The economic contribution of carbon revenues is discussed in more detail in the case study in the next part but for the discussion on barriers it is important to mention that carbon finance addresses the negative externality caused by carbon emissions. By generating additional financial benefits for clean technologies price distortions are reduced. But this effect only comes effective when CDM transaction costs and barriers to the utilization of the CDM do not offset financial benefits. Based on the discussion above it can be argued that for micro-scale projects, barriers still exacerbate access to carbon finance though the PoA is much closer to rural electrification realities than stand-alone CDM projects, as it offers the opportunity to progressively add CPAs according to programme development and success. However, rural electrification experts point out that in general carbon and environmental considerations do only play a subordinate role in RE projects (Drenkard, 2010; Wiese, 2010). Emission reduction considerations are predominantly driven by the donor community but the major concern is economic viability and especially for solar PV contributions of carbon finance are

low so that from a financial viability perspective diesel grids might be the preferable option (Drenkard, 2010).

Another market performance barrier that has to be tackled is the establishment of a commercial infrastructure or distribution network (Wiese, 2010). In the case of MEL projects linked to the carbon market, MFIs can be seen to accomplish a double function: Building on existing MFI infrastructures and their access to the rural population ensures both a functioning distribution network for micro-energy systems and a monitoring infrastructure reducing CDM transaction costs.

An overview of barriers to rural electrification, which the two financing mechanisms address are presented in the table below.

Table 4: Barriers to Rural Electrification addressed by Carbon- and Microfinance

Type of Finance	Level of Removal	Barrier
Microfinance	Fully	Lack of Access to Credit for end-users* Lack of Information among end-users
	Partly	Lack of Market Infrastructure & Distribution Network High initial upfront costs for end-users High Transaction Costs
Carbon Finance	Partly	Environmental Externalities High initial upfront costs for end-users and providers Lack of Capacity & Information

Source: Author. *Access to credit for RE is provided for end-users, who would otherwise not have the opportunity to finance RE technologies but this does not apply to the poorest of the poor.

In general, developing countries focus much more on grid extension neglecting rural off-grid electrification (Bahnsen, 2010; Drenkard, 2010; Wiese, 2010). When the pCDM successfully proves to be a mechanism for dispersed micro-scale activities including RE technology dissemination, it could also have the potential to alter priorities. And though additional financial resources are still needed the carbon market should be utilized for financing micro-energy projects (Neufeld, 2010). Financial contributions of the CDM can increase in the future, especially, when RE prices continue the downward trend (Wiese, 2010), when prices for carbon certificates increase (Bahnsen, 2010; Steidl, 2010), or when suppressed energy demand (see appendix) is included in pro-poor baseline calculations (Bahnsen, 2010).

What is particularly important now is the implementation of demonstration projects that proof feasibility and serve as a benchmark for replications (Arens, 2010; Bahnsen et al.,

2009). Therefore, donor-funded initiatives are of major importance as they might pave the way for commercial PoA projects, which can build on the experience and benefit from existing CDM documentation. In order to learn from these projects it is equally important to analyse pioneer projects and to identify factors of success and difficulties these projects face. Such a pioneer project is introduced and analysed in the next section.

5 Applied Analysis: Case Study of the IDCOL Solar Energy Programme

The IDCOL Solar Energy Programme (ISEP) in Bangladesh serves as a Case Study to analyse how the project addresses barriers to rural electrification and to the carbon market and what obstacles it currently faces. A holistic economic analysis is beyond the scope of this paper (a good example for SHS is provided by Meier (2003)) and the clear focus is on the PoA project design, MEL and a multi-criteria analysis in order to evaluate the project from a financial, social, environmental and technological perspective. The section begins with a brief introduction to Bangladesh's energy profile and CDM initiatives.

5.1 Energy Access Situation and the CDM in Bangladesh

Bangladesh is an *"energy-starved country"* (MoEF, 2009) and has been struggling with severe power shortages for about a decade (Mondal et al., 2010). The total electrification rate in Bangladesh is 41% and only 28% in rural areas, which leaves a population of 94.9 million without electricity (IEA, 2008a). Most important energy sources in rural areas are biomass for cooking, kerosene for lighting, which is even used by households with electricity due to unreliable supply, and dry cell batteries for TV, radio and other consumer electronics (Asaduzzaman et al., 2009). With an energy use of only 171.0 kilograms of oil equivalent (kgoe) per capita (WRI, 2005), Bangladesh certainly is below the threshold identified by Goldemberg (2004) of 1,000 kgoe per capita, where beneficial effects of energy on the HDI begin to decline. Consequently, the population of Bangladesh has a lot to gain from electrification but the country lacks the financial means for electricity grid extension, especially to remote rural areas (Barua, 2008; Ford, 2010; Mondal et al., 2010).

For grid-extension to be a cost-effective option electricity demand and the number of households in the service area, the load density, have to be above a certain threshold

(World Bank, 2008). While the population density is high in Bangladesh, the main problem is the low energy demand of electrified households, which challenges commercial viability of grid extension to remote areas with little or without industrial load. Furthermore, power supply is a serious problem and cannot keep up with demand resulting in load sharing and power cuts (Ford, 2010). At present, energy generation in Bangladesh is almost entirely dependent on fossil fuels, predominantly natural gas, which accounts for 82.81% of the total capacity (5823 MW) installed (BPDB, 2010). But Bangladesh has ambitious future targets for renewable energy sources aiming at a 5% share of electricity from renewables by 2015, and a 10% share by 2020 (REN21, 2010). An increasing share of renewables can help to fulfil multiple goals the government is pursuing. First, it can expand installed capacity, which is constantly below demand and thus impedes development and deters foreign direct investments (Olling, 2010). Second, it can help to ensure national energy security, third, contribute to the reduction of greenhouse gases (MoEF, 2009) and fourth, it can contribute to the aim of overall access to electricity by 2020 (Mondal et al., 2010). Achieving these goals will be a major challenge for a capital-constrained country like Bangladesh, and increasing energy demand amongst others driven by economic growth, ongoing industrialization and population growth (Mondal et al., 2010) will further impede goal attainment. Accordingly, cost-efficient micro-energy systems, such as SHS, play an important role in achieving national targets and in addressing the needs of the rural population (Kamal, 2010; Sadeque, 2010). Especially, as grid electrification proceeds at such a slow pace SHS are a reasonable solution (Ford, 2010), serving electricity for one of the key energy uses, lighting (Asaduzzaman et al., 2009).

Bangladesh also promotes SHS as part of its climate change strategy. For Bangladesh, being one of the most vulnerable countries to climate change, adaptation is priority, but nevertheless, the country strives for low carbon development and for the utilization of carbon finance (MoEF, 2009). The CDM could be one source to finance renewable energy development and to promote technology transfer and thus the country plans to increase and facilitate CDM projects (MoEF, 2009; Rahman, 2010). Currently, Bangladesh has two registered stand-alone CDM projects, both in the waste management field, and one stand-alone CDM project at validation, which is intended to address EE in the brick building industry. In addition, three PoA projects are at validation, an energy efficient cook stove programme, the dissemination of compact

fluorescent light bulbs (CFL) and the installation of solar home systems (UNEP Risoe Centre, 2010), which is analysed in detail in the next section.

5.2 Project Background and Design

The Solar Energy Programme is a small-scale PoA coordinated by IDCOL, a government-owned financial institution, with the goal to provide households and SMEs in off-grid areas with electricity by implementing SHS (IDCOL, 2010b). The IDCOL Solar Energy Programme did not initially start as a PoA but was commenced in 2003 as part of the Rural Electrification and Renewable Energy Development Project (REREDP) funded by the International Development Association (IDA) and the Global Environmental Facility (GEF) (Sharif, 2010a). By generating carbon revenues under the CDM, IDCOL hopes to increase the number of SHS installations significantly (IDCOL, 2010b). The analysis of this programme focuses on the period from 2007 as this is indicated as the starting date of the PoA (IDCOL, 2010b). However, the whole project period is taken into account whenever it serves the purpose of analysis.

5.2.1 Business Model and Implementation

The programme is implemented through NGOs and MFIs, referred to as Partner Organizations (POs), who are responsible for the selection of project areas and customers, for the provision of energy credits as well as the installation and maintenance of SHS (IDCOL, 2010b). Having experience in MF is an important criterion for the selection of POs (Sharif, 2010) and this institutional choice traces back to the REREDP, which intended to *"utilize[] the strengths of the vibrant NGO/MFI sectors in Bangladesh and make[] off-grid alternatives socially acceptable and commercially sustainable"* (World Bank, 2002). Accordingly, the programme heavily depends on the existing delivery infrastructure and client networks of MFIs. Currently, 23 POs[18] implement SHS under the programme (Reza, 2010a) and the largest institutions in terms of installed systems are Grameen Shakti, RSF and BRAC Foundation (IDCOL, 2010c).

IDCOL is the coordinating entity of the PoA and provides financing as well as technical assistance to the POs and monitors the programme (Sharif, 2010a). Financing provided to the POs to overcome financial gaps includes both grants and soft loans. The grant

[18] The PoA-DD only refers to 14 POs, as it was originally written in 2007 but indicates that further POs may be added (IDCOL, 2010b). Furthermore, 8 new POs are about to start implementing SHS (Reza, 2010a).

element is divided into two components, a capital buy-down grant to reduce the initial cost of the SHS and an institutional development grant to enable the POs to extend the programme and their capacity (Sharif, 2010a). Accordingly, the grant components address two important barriers to rural electrification, high up-front costs for end-users and a lack of capacity on the side of NGOs/MFIs.

Based on the design of the REREDP the grant amount continuously decreases based on the idea that grants are phased out once the programme is commercially viable (IDCOL, 2010b). Currently, the programme is at the last stage of subsidies provided, which initially started with a total grant amount of US$ 90 per system and is now down to €22 (US$ 29) per SHS. The buy-down grant is €20 and the institutional development grant €2 respectively, whereas new POs get €8 per system for institutional development (Islam, 2010; Sharif, 2010a). The grant amount is independent of the size of the SHS, which can vary between 10 Wp and 130 Wp (Islam, 2010a), and thus constitutes a social grant structure with higher grant percentages for smaller systems (Rahman, 2010; Wiese & Schacht, 2010).

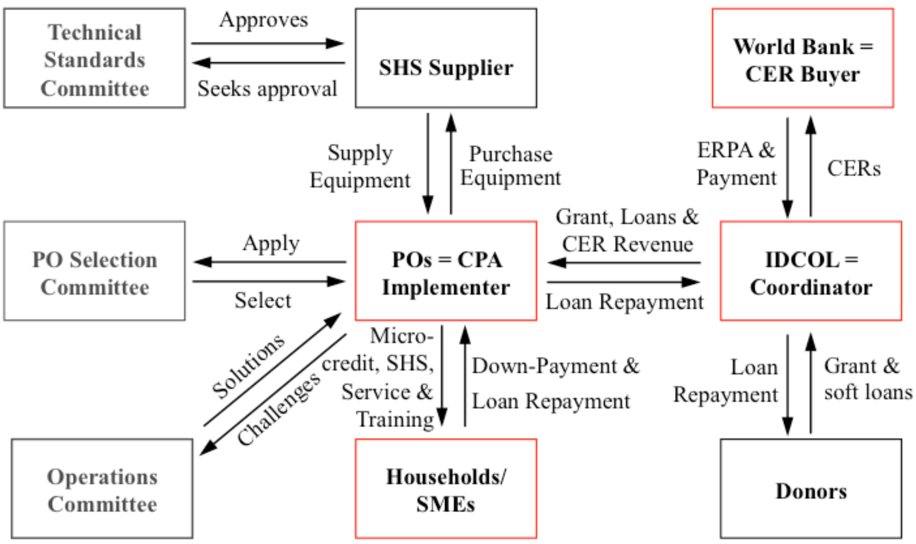
Soft loans for POs, the second component of financing provided by the coordinating entity, serve to refinance the credit granted to households. 80% of each micro-energy loan are provided by IDCOL at favourable loan conditions, including up to two years grace period and 6-8% interest for a 7-10 years maturity (Sharif, 2010a). Soft loans address the barrier of high upfront costs for providers, in this case the POs, and facilitate the extension of energy credits. Relating this to the discussion on carbon projects, upfront finance for project implementers is critical and usually not covered by carbon revenues and related ERPAs. The ISEP is able to solve this problem as the coordinating entity benefits from soft loans provided by international organisations. In contrast to the grant component, this part is unlikely to be covered by carbon finance, but nevertheless, carbon finance can enhance credit standing of the coordinating entity.

Technical assistance provided by IDCOL covers different training programmes. Training of trainers is provided to enable POs to train their own staff and IDCOL regularly supports staff training for installation and maintenance as well as customer training for adequate use of the system with both human and financial resources (Pavel, 2010). Offering such an extensive training programme acknowledges the importance of maintenance services and adequate client behaviour.

Next to IDCOL and the POs other actors involved in the delivery model are manufacturers and suppliers, who sell SHS and spare parts to the POs, three committees

ensuring quality of the programme and stakeholder involvement at different levels (IDCOL, 2010b; Sharif, 2010a). The Technical Standard Committee determines quality standards and approves equipment used by POs, the Operations Committee meeting once a month with IDCOL officers and representatives from each PO monitors the performance of the programme, and the PO Selection Committee decides on new POs based on their MF experience and financial strength (Pavel, 2010; Sharif, 2010a). An overview of the business model and parties involved is shown in the figure below.

Figure 7: Business Model of the IDCOL Solar Energy Programme



Source: Author revised from Sharif (2010a).

5.2.2 Monitoring Mechanism

CDM monitoring will be done by the coordinating entity IDCOL (Islam, 2010a). As a financial institution, IDCOL has a strong capability to handle financial flows and to monitor POs. CDM monitoring can be perfectly integrated into the existing inspection process of IDCOL.

The process covers both inspections of newly installed systems to verify installation and inspections of older systems to ensure technical performance (Wiese et al., 2007). It is a continuous process that is organized on three levels: First, IDCOL inspectors monitor newly installed SHS and the current inspection rate is 45% (IDCOL, 2010d). Second, officers do re-inspections with an approximate rate of 100 SHS per months. And third, approximately 500 systems are inspected by a third party auditor once a year (Haque, 2010; Reza, 2010a).

The CDM methodology applied, type I.A electricity generation by the user, allows for both sampling and substitution of field inspections by loan repayments in order to

ensure continuing operation of systems (UNFCCC, 2010e). Accordingly, IDCOL will conduct annual inspections of a statistically significant sample to ensure real emission reductions and in addition provide monitoring reports including monthly installation numbers and loan repayment details (IDCOL, 2010b). This can easily be achieved as part of IDCOLs inspection process, which even exceeds CDM requirements, so that CDM monitoring can be accomplished at marginal additional costs.

Furthermore, IDCOL had a database in place, which was adjusted to CDM needs (IDCOL, 2010b). The database includes information on every single SHS and every system is uniquely identifiable based on an individual client number and the serial number of the panel to comply with CDM requirements (Haque, 2010).

Though the process seems to be uncoupled from MFIs at a first glance, the programme as such and monitoring benefit from the excellent local network of POs. Through existing and newly build up PO networks about 1,500 field offices are distributing SHS today so that the project succeeded in building a nation-wide infrastructure (Wiese, 2010) covering all 64 districts of Bangladesh (Reza, 2010) and thus the geographical boundary of the PoA. Accordingly, the programme utilizes and expands PO delivery infrastructure for the dissemination of SHS. IDCOL as such has no contact to SHS clients, except when field inspections are conducted with support of MFI staff. The MFI infrastructure and client network is thus not duplicated, but additional monitoring by IDCOL ensures performance of POs in both dimensions, loan recovery and technical services. Moreover, IDCOL is required to monitor PO performance in order to ensure refinancing of soft loans provided to the POs. Thus, it can be concluded that a business model involving a network of MFIs/NGOs and a financial institution as a coordinating entity is very suitable to integrate carbon projects.

Carbon crediting and repayment periods for energy loans diverge in the ISEP. Crediting periods are seven years with the opportunity to extend the period two times (IDCOL, 2010a), whereas the loan period for SHS clients is only two to three years (Grameen Shakti, 2010a). Loan repayment can thus only be reported for a fraction of the carbon crediting period. In order to establish a long-term client relationship, POs offer maintenance services at minimal cost after repayment, while the service is for free for the first three years (IDCOL, 2010b) acknowledging that after-sales services are key for loan repayment and technical performance. Clients can voluntarily enter the maintenance agreement for an annual service charge of BDT 300 (US$ 4.26) (Rabbi, 2010), which can not only ease carbon monitoring but also increase the lifetime of the

SHS. However, clients are very reluctant to enter such an agreement, probably as they do not see a need (Islam, 2010; Rabbi, 2010). The only statistics available are from Grameen Shakti: As of November 2010 out of 109,929 fully paid systems for only 19,524 maintenance agreements exist (Grameen Shakti, 2010b). Accordingly, only 17.8% of clients have a maintenance agreement that perpetuates the relationship between POs and the client. But another measure is provided under the ISEP to facilitate that IDCOL or POs take notice of SHS which are not operating. Warranty periods guaranteed for different parts of the system can be seen as a mechanism in place ensuring detection of technical problems and a constant relationship to the client, e.g. 5 years warranty are granted for the battery and 20 years for the panel respectively (Islam, 2010). Hence, clients are provided with security on system performance and IDCOL and POs retain a relation to the client – at least when technical problems occur.

5.2.3 Use of Carbon Revenue

As indicated in figure 9 the ISEP has an ERPA with the World Bank covering all achieved emission reductions until 2012 at a CER price of €9 (US$ 11.84) (Haque, 2010). The World Bank has an option to buy certificates until 2015 and also the Asian Development Bank (ADB) shown interest in carbon credits generated under the PoA for the post-2012 period (Haque, 2010) putting IDCOL in a comfortable position. Carbon titles from all POs but Grameen Shakti, being the largest CPA implementer, are transferred to IDCOL (IDCOL, 2010b), whereas IDCOL will retain a portion of revenues and pass on the major share to the POs (IDCOL, 2010a).

According to the PoA-DD and the CPA-DD, CDM revenues generated are planned to fill different financial gaps. First and foremost, phasing out of the subsidy element is a key argument used for the demonstration of additionality. The programme is still not commercially viable without subsidies and thus carbon finance is intended to be utilized to implement the programme with reduced grants (IDCOL, 2010b).

The consulted POs indicate that they plan to use CDM revenues for battery or system price reductions, training and for scaling up the programme (Barua, 2010; S. Islam, 2010; Ullah, 2010), all opportunities of CDM revenue usage also outlined in the CDM design documents. Furthermore, it is planned to address technical and informational barriers with carbon revenues by financing initial free maintenance services, customer and technicians training as well as awareness raising (IDCOL, 2010a; IDCOL, 2010b). And in order to address the credit risk involved in the programme, carbon revenues can

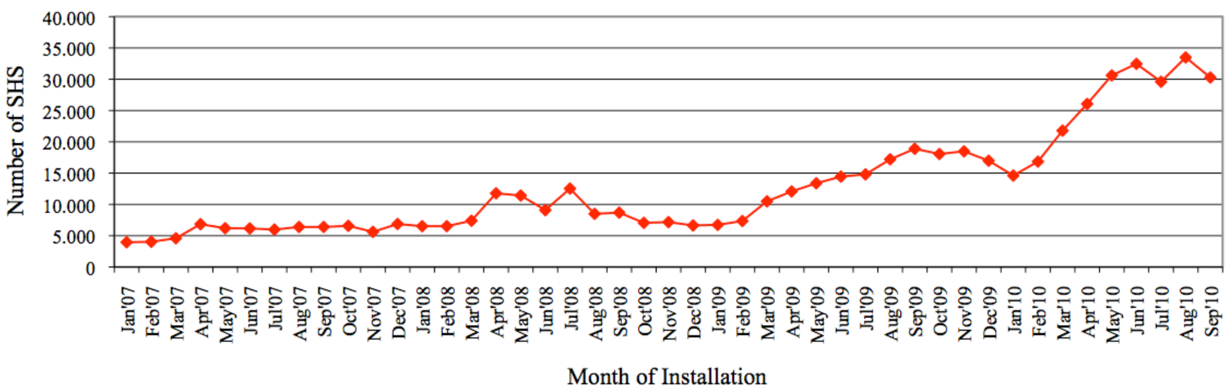
serve as a buffer for loan defaults to cover non-repayments of an estimated 3,840 loans per year (IDCOL, 2010b).

Certainly, possible uses for carbon revenues are wide but it should be kept in mind that the number of generated CERs by solar PV is limited. Whether it is an option to use CDM revenues for the intended applications is further discussed when calculating the financial contribution of CDM revenues in the MCA in the following.

5.2.4 Challenges of the Programme and Obstacles to CDM Registration

The success of the programme itself is becoming a problem. The programme has grown significantly from 2007 to 2010 with monthly installation rates of 4,000 to 6,000 systems in 2007 (Wiese et al., 2007a) and more than 30,000 systems in 2010 (IDCOL, 2010c). Monthly installations of SHS under the ISEP are shown in the graph below.

Figure 8: Monthly Installations of SHS from 2007 to 2010



Source: Author based on data from IDCOL (2010c).

In particular, ensuring the quality level of equipment and keeping up with the training of loan officers and clients, all key components for the technical performance, are becoming a challenge (Husain, 2010; Islam, 2010; Quddus, 2010; Rahman, 2010; Sharif, 2010). Local assembling of SHS spare parts and the battery industry in particular, which owes its growth in Bangladesh to the ISEP programme[19], have problems to keep up with the growth pace impeding compliance with technical standards (Rabbi, 2010). To keep up with demand POs employ high numbers of staff, who do not get trained well (IDCOL, 2010e; Steidl, 2010) and also finding qualified people is an increasing problem, as Bangladesh does not have an educational institution specialized in solar energy (Sharif, 2010). But still, the willingness of POs to invest in training is limited (Pavel, 2010). Under-qualified staff and the strong focus on growth

[19] Battery import is no option due to a 67% import tariff (Islam, 2010).

result in higher numbers of improper installations and hence, external consultants and donors highly recommend to increase PO investment in training (Rahman, 2010; Steidl, 2010). In addition, IDCOLs inspections of PO unit offices showed that more than 30% of unit offices inspected do not perform satisfactorily in terms of credit risk and collection efficiency (IDCOL, 2010f; IDCOL, 2010g). Thus, both POs and IDCOL should shift the focus from growth to management and monitoring (Sadeque, 2010).

Experts indicate that the peak, i.e. market saturation or a termination of international support, will be the *"stress-test"* (Steidl, 2010) for POs (Sadeque, 2010; Steidl, 2010). It can be deduced that high numbers of installations are attractive for POs as they receive down payments from SHS customers, the institutional development grant from IDCOL and a soft loan for 80% of SHS cost. However, when installation rates stagnate or even decrease POs must be prepared to finance their micro-energy programme from timely collection, service fees for maintenance and carbon finance only. In conclusion, a strong focus on proper installation, maintenance services, and collection of loan instalments is crucial for the sustainability of the ISEP in the long run (compare IDCOL, 2010e).

Addressing CDM-related barriers outlined in the prior chapter, the time lag of the CDM project cycle and complexity pose critical barriers to the programme. The PoA officially started with the period for comments in December 2007 (UNFCCC, 2010c) and has since been in validation. The first CPA and additional SHS, which could have been added as CPAs to a registered programme, are already implemented and operating. Consequently, achieved emission reductions do not generate CERs and represent lost revenues, as retroactive crediting is not allowed under the CDM. Based on the estimated emission reductions per SHS calculated in the CPA-DD lost revenues due to the delay from project design to registration account for US$ 1,401,486 (nominal value)[20].

The obstacles project developers have been facing during the PoA project cycle are the establishment of the baseline, time-consuming DOE validation and adequate revision of the required CDM documentation as well as the determination of additionality (Haque, 2010; Islam, 2010a; Sadeque, 2010). No baseline survey for SHS in Bangladesh to determine achieved emission reductions existed and a complete survey had to be conducted. In addition, no SHS PoA has been registered under the CDM that could have

[20] Based on actual installations from 2007-2009 assuming that verification of CERs is achieved one year after implementation and without taking CDM transaction costs into account. CER price is €9 (US$ 11.84).

served as a reference case, therefore the whole process can be seen as a learning process for all parties involved (Haque, 2010; Sadeque, 2010). To the contrary, after successful registration, which is expected to be in the beginning of 2011 (Haque, 2010), the project can serve as an example for other SHS PoA projects (Sadeque, 2010).

Additionality is hard to establish for the ISEP, as the project had already been implemented and running successfully before it considered carbon finance. In addition to decreasing subsidies, further barriers to the programme are discussed to demonstrate additionality, which is a common approach by project developers (Hinostroza et al., 2009). Barriers outlined are investment, technological, informational and institutional barriers (IDCOL, 2010b). However, the ISEP complies with the new additionality test for VSSC rural electrification projects (see appendix), which was unfortunately released after the programme started the carbon project cycle. In addition, as almost all rural electrification projects are dependent on subsidies (World Bank, 2008a), also the ISEP depends on grants and soft loans to run the project successfully, it would only be reasonable to co-finance the project with carbon finance. Certainly, the programme will also continue without carbon revenue, but when grants are completely phased out growth is expected to run at a lower pace (Haque, 2010) and grant reductions will especially hit the poorer target groups.

In contrast, upfront CDM transaction costs did not pose any barrier for the ISEP as the World Bank ERPA covered all relevant preparation costs (Haque, 2010). Moreover, CDM-related monitoring costs are negligible as IDCOLs monitoring process exceeds CDM requirements (Haque, 2010; Pavel, 2010).

To sum up, with the infrastructure in place CDM transaction costs did not pose a barrier for the ISEP but complexity of the process and CDM documentation do pose an obstacle. The programme is still not registered under the CDM and growing at a high rate also without carbon finance. However, the programme depends on grants and lower upfront costs are especially important to target lower income groups. The contribution carbon finance can make to the programme and other indicators to evaluate the ongoing programme are calculated and discussed in the next section.

5.3 Multi-Criteria Analysis

The MCA serves to assess the impact and performance of the ISEP in the three sustainability dimensions as well as the institutional and technological dimension, both critical for the success of the programme in every aspect. Case-specific indicators for a

MEL project utilizing carbon finance are defined and calculated on the basis of quantitative data and the results are discussed and substantiated with qualitative information.

5.3.1 Financial Dimension

The financial contribution of carbon revenues is decisive for the attractiveness of the CDM and crucial when carbon finance serves to overcome financial barriers. What makes calculations of financial contributions difficult in the case of a PoA project is that the overall size is unknown in the beginning (Hayashi et al., 2010). For the purpose of the net present value analysis of the financial contribution of carbon finance the size of the PoA is calculated based on actual installation numbers from 2007 to 2010 and on estimates for 2011 to 2014, which are based on current average monthly installation rates. The final size of the PoA is assumed to be conservative as installation rates have constantly increased in the past. The average growth of the programme between 2003 and 2010 amounted to 61% (IDCOL, 2010c), whereas calculations are based on a growth rate of only 18% from 2010 to 2011 (author's calculations based on IDCOL, 2010c), and constant installations in the following years. Furthermore, the total number of installations is smaller than the intended growth by IDCOL which amounts to 2.5 million installed SHS in 2014 (IDCOL, 2010d). For the purpose of this financial analysis it is assumed that small-scale CPAs are added in the period from 2011 to 2014. However, additional CPAs could be added after that period, which would further reduce CDM transaction cost per SHS. The most important assumptions are presented in the table below.

Table 5: Assumptions for the NPV Analysis of CDM Revenue Contributions

Final Size of PoA	CERs per SHS (Year)	SHS Lifetime	CER Price (US$)	Discount Rates
2,102,211 SHS	0,24 > 30 Wp 0,11 ≤ 30 Wp	20 Years	Scenario 1: 11.84 (whole term) Scenario 2: 20.00 (post-2012)	Rate 1: 10.00% Rate 2: 6.35%

Source: Author. Note: A detailed overview of sources and argumentations is provided in the appendix.

Estimations for accruing carbon transaction costs are based on the existing World Bank ERPA covering project preparation cost and CDM transaction costs in the first three years (World Bank, 2007) and cost estimations from Hayashi et al. (2010). An overview is shown in the table below.

Table 6: Overview of Estimated CDM Transaction Costs

	CDM Cost Components	US$ (nominal)	Assumptions
Costs covered by ERPA	Project Preparation Cost (PIN, PoA-DD, CPA-DD, validation)	200,000.00	Project assessment and review, preparation & review of Project Documents and CDM Operation Plan, Validation of the CPA.
	CDM-Transaction Costs for 3 consecutive years	100,000.00	Kyoto Protocol and other costs for three years (incl. monitoring, verification and certification). No additional costs are expected to occur in the first three years.
Annual Costs	Monitoring	3,000.00	Annual payments to cover statistical significant sample size. Marginal and fixed as the sample is expected to be of same size.
	Validation/Inclusion (CPA-DD, DOE fee)	15,000.00	Predominantly DOE-fees. CPA-DD preparation can be based on generic CPA-DD and prior documents. Costs accrue in years where CPAs are added (2010 - 2014).
	Verification	15,000.00	Verification of CPAs by DOE. Costs accrue every year.
	Renewal of Crediting Period	15,000.00	Updated documents must be validated and confirmed by a DOE. Costs accrue when any crediting period is renewed.

Source: Author. Note: Detailed argumentations for the assumptions are provided in the appendix.

While cost estimations for project preparation compared to those provided by Hayashi et al. (2010) are rather at the upper end, cost estimations for the operational phase of the PoA are at the lower end. First of all, projects in LDCs are exempted from the administration share of proceeds and small-scale projects benefit from simplified methodologies. In addition, the MFI/NGO infrastructure serves to disseminate SHS efficiently and monitoring is included into IDCOLs existing business, resulting in marginal annual costs (compare also Hayashi et al., 2010). The NPV analysis shows that the cost share per SHS with such a large number of systems installed is marginal with a nominal value of US$ 0.39 and present values at different discount rates of US$ 0.2 and US$ 0.25 respectively. Even doubling annual operation cost would thus not reduce CER revenues significantly. The table below summarizes the results and shows carbon revenue generation per SHS over its lifetime. Costs and benefits are equally spread over the systems, independent of size following the grant structure of the ISEP and ignoring that smaller SHS generate less emission reductions.

Table 7: Contribution of Carbon Finance per Solar Home System

	Nominal Value (US$)	NPV$_1$ (US$)	NPV$_2$ (US$)
CER Price Scenario 1	47,76	17,73	24,44
CER Price Scenario 2	78,65	29,14	40,26

Source: Author. Detailed calculations can be found in the appendix.

As indicated in the literature, the contribution of carbon finance for solar PV is limited, which suggests that revenues cannot serve all the intended usages outlined above. In the

following the results of the NPV calculations are related to the decreasing buy down grant, which was used as an argument for the additionality of the PoA, and the lack of training, which is becoming a problem under the programme.

The buy down grant currently amounts to US$ 26.31 (€20) and can thus not be covered by net present values calculating with the current CER price paid by the World Bank. However, at a discount rate of 6.35%, the interest rate of deposits paid by commercial banks in Bangladesh, the net present value gets very close to current grants. When CER prices after 2012 rise to US$ 20, relying on the fact that small-scale renewable energy projects get a premium price, and solar in particular (compare also Chaurey & Kandpal, 2009; Kossoy & Ambrosi, 2010), grant amounts could even be increased. To what extent carbon finance can reduce the initial cost of differently sized SHS is shown in the table below. Reductions of upfront costs, a major barrier to rural electrification and renewable energy technologies, are calculated for 50 Wp systems, the most popular PV in the programme (Ullah, 2010) and 20 Wp systems.

Table 8: Percentage Cost Reduction of SHS due to Carbon Finance

	% Cost reduction 50 Wp (nominal)	% Cost reduction 50 Wp (NPV_1)	% Cost reduction 50 Wp (NPV_2)	% Cost reduction 20 Wp (nominal)	% Cost reduction 20 Wp (NPV_1)	% Cost reduction 20 Wp (NPV_2)
CER Price Scenario 1	12.57%	4.67%	6.43%	28.09%	10.43%	14.38%
CER Price Scenario 2	20.70%	7.67%	10.60%	46.26%	17.14%	23.68%

Source: Author. Note: Initial cost of a 50 Wp SHS are US$ 380 and of a 20 Wp SHS US$ 170 (Sharif, 2010a).

The results clearly show the integrated social component of spreading costs and benefits equally over SHS independent of size, which is also applied by the current ISEP grant structure. While cost reductions for a 50 Wp SHS account for almost 6.5% at current CER prices and the lower discount rate, cost reductions for a 20 Wp SHS are more than twice the percentage reductions and account for more than 14%. Under the higher price scenario cost reductions for a 20 Wp system even account for almost a quarter of initial SHS cost.

However, price reductions for SHS was not the only need for finance outlined in the PoA-DD. Further financial resources are needed for staff and customer training, which is important to ensure proper installation, maintenance and use of the SHS. The training cost per staff is BDT 1,350 (US$ 19.15) and per customer BDT 150 (US$ 2.13) (IDCOL, 2010e). Accordingly, at present values calculated with current CER prices paid by the World Bank and a discount rate of 6.35% carbon revenues of one SHS could

finance the training for two clients and one technician. Accordingly, carbon finance could easily cover staff and customer training, even when applying higher discount rates, as there is certainly no need for one technician per SHS.

In order to be able to finance both buy down grants and training a pro-poor approach to distribute carbon revenues would be to support smaller systems ≤ 30 Wp with grants in particular and use remaining financial resources for training. Under the ISEP it is still difficult to reach poorer target groups and further price reductions in forms of grants would be needed (Rabbi, 2010). Thus, carbon finance could contribute to reaching even poorer target groups, which would be a major contribution to sustainable development, the second objective of the CDM.

5.3.2 Social Dimension

First, it should be stressed that households targeted by the SHS programme are living in off-grid areas (IDCOL, 2010b) who would otherwise have no access to electricity. The currently installed 680,000 systems bring electric light to around 3.4 million people[21] in Bangladesh (Sharif, 2010a). But from a social perspective it is not enough to provide access to energy, it must also be affordable for the rural population. In order to calculate potential energy cost savings and the benefit of the investment, the NPV of avoided costs for a 50 Wp SHS with a loan period of 36 months, the most common scenario under the programme (Barua, 2010), and the IRR are calculated. The cases are based on the assumption that no income generation is achieved with the SHS (compare Mondal, 2010). The indicators are calculated for two scenarios to account for different income levels: A household replacing two hurricane lamps and a battery and a household replacing a hurricane lamp and a kupi only[22]. In addition, both scenarios are calculated with and without increasing kerosene prices and carbon finance. The most important assumptions for calculations, which are assumed to be conservative, are presented in the table below.

[21] Installations as of September 2010; Based on an average household size of 5 members.

[22] Kupis and hurricane lamps are the major types of kerosene lamps used in Bangladesh, whereas kupis are uncovered lamps and hurricanes have a glass chimney and thicker wicks. Per 100 households without electricity 90.3 hurricane lamps and 182.8 kupis are in use (Asaduzzaman et al., 2009).

Table 9: Assumptions for NPV and IRR Calculation

Option: 50 Wp SHS		**Replacement: Kerosene Lamps and Battery**	
Loan Conditions	36 months, 12% interest, 15% down payment	Kerosene Replacement	95.2 liter/annum
		Kerosene Price Increase	3%/annum
Panel Lifetime	20 Years	Hurricane Replacement	4 Years
Battery Replacement	5 Years	Kupi Replacement	1 Year
Controller Replacement	3 Years	Battery Replacement	3 Years
Lamp Replacement	3 Years	Battery Charging	2 times/months
Cable/Support Structure	5 Years		
Maintenance Agreement	After Repayment Period		
Discount Rate 1: 13% Lending Rate for Housing Loans at Commercial Bank Discount Rate 2: 6.35% Interest Rate of Deposits paid by Commercial Bank			

Source: Author. Note: Prices, sources and all assumptions as well as SHS technology is presented in the appendix.

As shown above the benefits generated by a SHS are avoided costs for kerosene, battery charging and equipment replacement costs, while costs incurred for the SHS are the initial down payment and loan repayments as well as the replacement of spare parts and a maintenance agreement entered voluntarily after the three years loan period. The results are calculated on an annual basis and are presented and discussed below.

Table 10: Scenario 1 – NPV and IRR Results

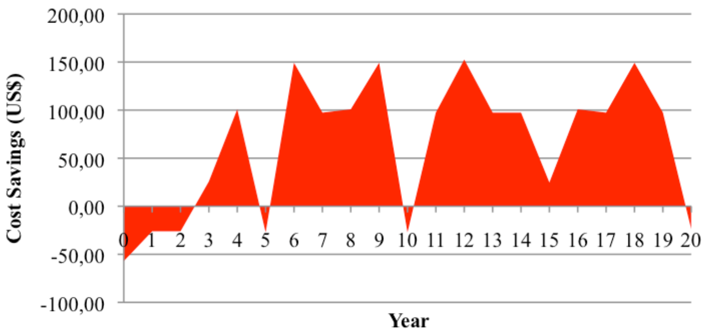
	PV_1 Basic Results (US$)	**PV_2 Basic Results (US$)**	**PV_1 Results with Carbon Credit (US$)**	**PV_2 Results with Carbon Credit (US$)**	**PV_1 Kerosene Price Increase (US$)**	**PV_2 Kerosene Price Increase (US$)**
NPV	309.52	636.07	328.20	665.73	410.47	841.83
IRR	37.89%		39.74%		42.52%	

Source: Author. Note: Detailed Calculations can be found in the appendix.

For a household replacing a battery and kerosene lamps NPV results are positive throughout all scenarios and the IRR clearly exceeds both discount rates. Thus, it can be concluded that the investment achieves significant cost savings for rural households. A project assessment of the World Bank (2009a) presents similar results for the basic results and those including carbon credits. However, the IRRs in the project paper are slightly lower with 32.8% and 33.7% (World Bank, 2009a). This can partly be explained by a lower kerosene consumption pattern the study refers to. The analysis at hand uses baseline calculations presented in the PoA-DD, which are based on a representative baseline survey and which are assumed to be conservative. Doing a sensitivity analysis with only half the annual kerosene consumption, i.e. 47.6 litres per annum, still gives positive NPVs and IRRs of 19.92%, 20.61% and 22.66% respectively. Accordingly, even for households consuming less kerosene a SHS is a financially viable option. Improvements of the economic viability due to carbon finance, calculated based on the assumption that carbon revenues are paid annually to the household, are marginal. It seems more reasonable to grant SHS customers price reductions when cost savings are negative, i.e. when costs for the SHS increase avoided

costs. As can be seen in the figure below this is the case in the first 2.5 years and in the years 5 and 10, i.e. when the battery has to be replaced.

Figure 9: Net Financial Flows for SHS Customers



Source: Author. Note: In year 15, SHS battery replacement and cost savings from car battery replacement coincide.

Whether households only replacing kerosene lamps with a 50 Wp SHS also achieve cost savings is analysed below.

Table 11: Scenario 2 – NPV and IRR Results

	PV_1 Basic Results (US$)	PV_2 Basic Results (US$)	PV_1 Results with Carbon Credit (US$)	PV_2 Results with Carbon Credit (US$)	PV_1 Kerosene Price Increase (US$)	PV_2 Kerosene Price Increase (US$)
NPV	-138.95	-85.45	-120.26	-55.79	-38.00	120.30
IRR	1.69%		3.39%		10.75%	

Source: Author. Note: Detailed Calculations can be found in the appendix.

All NPV results but the last, including increasing kerosene prices and a discount rate of 6.35%, are negative. Negative results for households only replacing lamps by a SHS are also reported by other studies calculating the benefits on the basis of avoided costs but these studies also indicate that the willingness-to-pay is above replacement costs (Mondal, 2010; Munasinghe, 2009). Tough the main reason for clients to buy a SHS is lighting – all households in the field reported lighting to be the main motivation to buy a SHS –, TV, mobile charging and other applications are valued benefits of the system (Rabbi, 2010). And as shown in the calculations including battery replacement a SHS is the least cost alternative for rural households to get these benefits. Accordingly, it can be argued that households increase their energy consumption when a cheaper option than a car battery exists. This assumption is also confirmed by the data collected during field visits. All but one household did not have a battery before and all households visited had a 50 Wp or larger system. Thus, the willingness-to-pay for the services provided by the SHS is well above historical energy expenditures (compare Mondal, 2010; Munasinghe, 2009) as systems improve the quality of life beyond cost savings.

When combining carbon finance and kerosene price increases the NPV discounted at 6.35% further increases to US$149.97 and the IRR to 11.75%, which comes close to the higher discount rate of 13%. In addition, it is important to mention that a financial analysis is conservative, as it does not include health and other welfare benefits, such as local air quality and quality of light (compare Asaduzzaman et al., 2009; Mondal, 2010; Meier, 2003). As an example, electricity provides 100 times more light than a kerosene lamp facilitating educational activities and indeed studies confirm that rural electrification is related to improved education (Asaduzzaman et al., 2009). Half of the households surveyed explicitly mentioned their children's education as the main need for high-quality lighting, implying that in the long-term, non-productive energy loans can also have economic development impacts due to better educational outcomes. Also improved health augments productivity and reduces health expenditures. Including these externalities in addition to the environmental externality, which is partly addressed by carbon finance, would increase both the NPV and IRR of a SHS.

Moreover, it should be highlighted that next to cost reductions solar, or renewable energy in general, supports the individual energy autonomy of clients. It can reduce *"energy security risks*" (van der Vleuten et al., 2007) significantly – on an individual but also on the national level (Ford, 2010; Modi, 2004). For Bangladesh, having limited financial capacity and facing depleting natural gas resources and rising fossil fuel prices (Kamal, 2010), renewables could decrease the dependency on fossil fuel imports and thus promote energy security. And while in this study fossil fuel price increases are conservatively assumed to be 3% per annum, other studies use higher price increases, such as 5% (for example Bhuiyan M.M.H. et al., 2000).

Besides all benefits, the field study indicated that clients have a frequent complaint: they are not allowed to use a fan. Fan usage at daytime inhibits adequate battery recharging lowering its lifetime significantly (Husain, 2010). The majority of households visited indicated that they would like to have a fan and one business client even used a fan. While this drawback of the SHS demonstrates that grid electricity offers a higher service level (World Bank, 2002) it is important to advertise the real capacity of a SHS in order to prevent too high expectations (Sadeque, 2010).

5.3.3 Environmental Dimension

Independent of the programme registration under the CDM emission reductions are achieved. According to the baseline presented in the PoA-DD emission reductions per

replaced kerosene lamp account for annual CO_2 reductions of kg 112.3 and per replaced battery charged by diesel for annual CO_2 reductions of kg 8.1 (IDCOL, 2010b). The number of kerosene lamps and batteries replaced is determined by the size of the SHS. Small SHS ≤ 30 Wp are assumed to replace one kerosene lamp only, whereas SHS ≥ 40 Wp and < 75 Wp replace two kerosene lamps. All SHS > 40 Wp are expected to replace a diesel-charged battery (IDCOL, 2010b). The average emission reductions per SHS in the first CPA are kg 244,5 CO_2/year (author's calculations based on IDCOL, 2010a), which is used as an approximation for all SHS > 30 Wp. As the number of small SHS increased significantly – in the first CPA small systems account for only 1.65% of installations (IDCOL, 2010a) but for 19.25% of current monthly installations (IDCOL, 2010c) – emission reductions of small SHS are only calculated with kg 112.3 based on actual numbers between 2007 and 2010 and estimates for post 2010. Achieved and expected emission reductions for different scenarios are shown in the table below. All calculations are based on an expected lifetime of the SHS of 20 years.

Table 12: Emission Reductions of the IDCOL Solar Energy Programme

	Cumulated No of SHS	Annual Emission Reductions (tCO_2)	Total Emission Reductions in (tCO_2)
SHS Installed	680,000	166,260	429,123
Expected Size of PoA	**2,102,211**	**463,863**	**8,998,686**
IDCOL 2014 Goal	2,500,000	611,250	2,247,167

Source: Author. Note: Emission Reductions for SHS Installed and IDCOL 2014 Goal are based on calculations with average emission reductions. Expected Size of PoA is adjusted for small SHS.

Annual emission reductions of the PoA account for only 0.01% of Bangladesh's annual CO_2 emissions, which amount to kt 43,715 (WDI, 2007). Certainly, on a national and a global scale these are marginal annual emission reductions. However, over the whole PoA duration the amount increases to $ktCO_2$ 8,998.69 and what is more important in accordance with sustainomics is the improvement of the quality of life without environmental degradation and at a low intensity of resource use. And this goal is certainly achieved with the dissemination of SHS.

5.3.4 Institutional Dimension

As an indicator for the institutional dimension the credit risk in the programme is presented, which is crucial for the financial sustainability of the programme and as both the literature and experts point out that credit risk of micro-energy loans is likely to be higher compared to microloans due to the additional technology risk. The indicator used

is PAR30, which is the standard measure in the MF industry to evaluate portfolio quality and which thus allows a comparison to MFI portfolios.

Quarterly data are available from June 2008 to September 2010, however, data are not complete for all POs and might not reflect the actual risk as they are self-reported by POs (compare also Wiese et al., 2007). Nevertheless, in order to conduct an assessment of credit risk, specific values are chosen and discussed.

The overall PAR30 based on self-reported data from 14 POs as of September 2010 is 9% (IDCOL, 2010i). On average, the PAR30 of the energy loan portfolio is 11% over the monitoring period and the data vary a lot between POs ranging from 0% to 47%, which is alarmingly high (author's calculation based on IDCOL, 2010i). In a MF context an indicator below 3-5% would be considered acceptable (Wiese et al., 2009a). Accordingly, financial risk is not adequately addressed in the programme (Steidl, 2010; Wiese, 2010).

What is of particular interest is whether energy-loans are related with higher credit risks compared to microloans. External experts monitoring the programme indicate that the energy-loan portfolios have a higher PAR than microloan portfolios (Steidl, 2010), which is analysed on the basis of some examples in the table below.

Table 13: Comparison of Portfolio at Risk of Micro-Energy Loans and Microloans

Partner Organization	PAR30 Energy Loans	Overall PAR30
BRAC Foundation	14,00%	8,01%
COAST Trust	21,00%	9,48%
IDF	33,00%	2,52%
TMSS	25,00%	4,05%

Source: Author based on data from MIX (2009a; 2010a; 2010b; 2010) and IDCOL {{;249 IDCOL 2010h; }}. Note: Data from BRAC Foundation as of December 2009 and all other data as of June 2010.

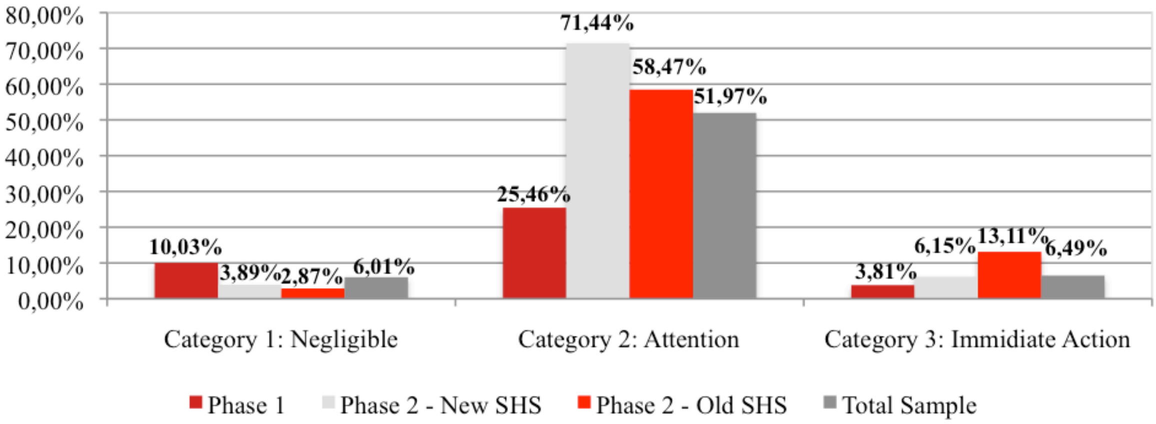
Comparing the percentages clearly shows that for all POs analysed the overall PAR30 is significantly lower than the PAR30 for energy loans indicating that additional risk factors are involved. Monitoring reports point out that *"many POs are not managed as professional microfinance institutions"* (Wiese et al., 2009a). In this context, it is important to point out that some POs manage energy loans as part of their MF business and others are renewable energy companies closely related to or founded by MFIs. What all POs have in common is that they follow the one-hand approach and offer equipment and technical service as well as financing. However, the cases analysed above are MFIs and seem to manage their microfinance portfolio much better than their energy-loan portfolio and POs indeed indicate that credit recovery is a major challenge (Quddus, 2010; Ullah, 2010). Accordingly, problems must be related to deficient

borrower screening, natural disasters, which are worse in the case of energy loans because not only repayment capacity is reduced but also the SHS subject to repayment is damaged, or technological deficiencies (compare Wiese et al., 2009a). These findings again underline that the programme should shift focus from growth to monitoring and collection.

5.3.5 Technical Dimension

As indicated above technical failures undermine emission reductions and thus carbon finance, increase credit risk for MFIs and reduce electricity provided to SHS clients. Technical monitoring to ensure error-free performance is thus key to the success of the programme. As an indicator for the technical performance deficiencies are divided into three different categories identified by external auditors, (1) negligible problems that can be corrected on site, such as a wrong angle of the PV module or shading, (2) problems that need further attention, for example the use of components of inferior quality not complying with technical standards, and (3) problems that require immediate action as they might lead to a damage or reduce the lifetime of the SHS (Wiese et al., 2007). Installation deficiencies of the last category are often concerning technical problems with or bypassing of the charge controller or problems with the battery (Wiese et al., 2009a). The problem categories are presented for two different monitoring phases, whereas the second phase is further subdivided into new (less than 12 months in operation) and old (at least 24 months in operation) systems (Wiese et al., 2009a). The percentages of inspected systems falling in the different categories are shown in the chart below.

Figure 10: Technical Deficiencies of Solar Home Systems



Source: Author based on data from Wiese et al. (2007a; 2007b; 2007; 2008a; 2008b; 2008; 2009a; 2009; 2010a; 2010). Note: Phase 1: May 07 – Aug 08, Sample Size 1,575. Phase 2: Nov 09 – Jun 10, Sample Size 1,901 New SHS and 732 Old SHS. Total Sample Size 4,208. All data are presented in the appendix.

The results clearly show that the technical performance deteriorates over the time period, confirming that growth is becoming a challenge. Especially, problems of category 2 show significant increases going up from 25% to 71% for new SHS and 58% for old SHS respectively. Deficiencies requiring immediate action more than double over the period, while severe problems are more common among old SHS. However, the overall percentage of problems requiring immediate action is low with only 6.5% and this is probably the most important indicator for the technical performance of the programme. More concerning is the high number of problems that need attention. The dominant problem in this category is the use of below quality or too long wiring, resulting in a voltage drop of the system (Husain, 2010; Wiese et al., 2010a). Although these problems do not damage the system, they are easy to avoid provided that well-trained technicians install and maintain the systems. This again underlines that POs must intensify staff training, which is also confirmed by external consultants pointing out that insufficient training is reflected in the increasing number of problems (Wiese et al., 2010). As remedial measure IDCOL does not pay any grants or loans to POs for any SHS where installation problems were detected until problems are fixed (Pavel, 2010).

Data on technical deficiencies due to client misbehaviour are only available for a limited number of periods. The most severe problem is bypassing of the charge controller, which results in over- and undercharging of the battery and as a consequence a drastic reduction of the battery lifetime (Drenkard, 2010). In the monitoring period from November to December 2009, for example, 23% of category 3 problems of newly installed SHS are due to bypassing of the charge controller while the number for old SHS is significantly lower with only 7.8% (Wiese et al., 2009a). Though this is only a short observation period it indicates that customer training on proper use of the system deteriorates. However, battery failures within the warranty period are reported to be below 1% (Islam, 2010) indicating that problems with bypassing of the charge controller or appliances not allowed for the SHS are limited. And again, once this problem is detected grants are deducted for the system as POs are responsible for client training (Husain, 2010).

5.4 Discussion and Results of the Multi-Criteria Analysis

Based on the financial indicator presented in the MCA it can be concluded that carbon finance contributes to the economic viability of the programme. However, contributions are marginal and the CDM does not address major financial hurdles for renewable

energy, which is confirmed by Satoguina (2006). Hence, optimal deployment of generated financial resources must be planned carefully. At current CER price levels carbon finance does not reduce high up front costs of SHS significantly. Nevertheless, it can serve to overcome other barriers, such as the lack of information and capacity by financing staff and customer training. Furthermore, it must be taken into account that when carbon revenues should serve as a substitute for buy down grants, there must be a mechanism in place to monetize future revenues today or to get loans for this purpose at favourable conditions to avoid further revenue reductions. This again demonstrates that revenue streams of carbon finance and MEL are not well matched. From this perspective, it could be argued that grant payments are more reasonable once revenues are generated. Based on the analysis of the net financial flow for SHS customers, grant payments financed by carbon revenues do not only make sense at the time of the SHS purchase but also when batteries, which account for about 40% of system costs, have to be replaced and this is also an option envisaged in the PoA-DD.

From a social perspective results based on the avoided-cost-method show that SHS are the least cost option in off-grid areas. Even without carbon finance SHS are financially viable and carbon finance has an impact of below 2% on the IRR. Results of the field research showed that the willingness-to-pay of some clients is above prior energy expenditures, which is confirmed by other studies. Accordingly, some households increase their energy consumption with the availability of a SHS. But calculations showed that when kerosene price increases are included, a 50 Wp SHS could even be the least cost option for households only replacing kerosene lamps. However, keeping in mind high up-front costs this is no possibility for the poorest of the poor. For them a smaller SHS would be the best option. And in general it is a criticism of SHS that they do not target the poorest households (Sharif, 2010; Wiese, 2010), which is also true for MF and especially for individual loans (Steidl, 2010). Also under the ISEP it is still a problem to reach poorer target groups, for which further price reductions in forms of grants would be needed (Rabbi, 2010). But still the number of small SHS systems, i.e. 10, 20 and 30 Wp, constantly increases and these sizes of SHS are outlined by Meier (2003) as an option for the poorest households. In December 2008 a total of only 1,243 small SHS were installed, while the average monthly installation rate today is at 5,856 systems (IDCOL, 2010c). As indicated above, carbon finance could particularly be used for price reductions of smaller systems in order to increase the affordability for lower income groups. Despite this criticism it is important to note that – and the success of the

programme is proof of that – there are people who can afford the technology, who benefit from the impacts and who would otherwise have no access to electricity independent of their income level.

From a social perspective it would furthermore be interesting to evaluate the impact on economic development but unfortunately, a lack of data detains effective evaluation. Nevertheless, a short paragraph should be dedicated to this important topic, as electricity is *"a catalyst for economic development"* (Ford, 2010), just as access to finance is important for economic progress (Steidl, 2010). Unfortunately, when it comes to economic development, the impact of SHS cannot live up to the impact of grid electricity, especially not when addressing the productive use of energy (Ford, 2010). Experts refer to SHS as a means of pre-electrification or mid-term solution (Drenkard, 2010; Ford, 2010) and the literature claims that they do not have effects on the economic development of the community (Ilskog & Kjellström, 2008). Nevertheless, some SHS clients in Bangladesh, usually shop owners, use their system for productive purposes, such as longer opening hours and renting out light (Steidl, 2010; Wiese, 2010). The two shop-owners visited estimated their increase in income to be 30-40% and 50% respectively, and both offered longer opening hours, one mobile charging services and the other one public TV. Although these increases are assumed to be exaggerated, income increases by offering new services are realistic and confirmed by other studies (for example Mondal, 2010). However, approximately 80% of the clients are household and not business clients (Islam, 2010a; Rabbi, 2010). Still, it can be argued that there are some immediate spill-over effects on the community, namely better access to information, communication and entertainment and in some cases also lighting. And again it should be highlighted that non-productive energy loans for SHS can have significant impacts on economic development by improving educational outcomes and health conditions as well as providing opportunities, especially for women, to start income-generating activities from their homes.

The questions whether SHS promote environmental sustainability is easy to answer. The more systems are installed, the more CO_2 emissions are reduced though emission reductions are marginal on a national or global scale. However, it is a contribution to climate change mitigation and more importantly, a step upwards on the energy ladder from traditional to clean energy sources. Another topic relevant in an environmental context is battery recycling. Though there is no indicator defined for this due to a lack of data, it should briefly be discussed as battery recycling is identified as the only

environmental impact of SHS (IDCOL, 2010b). To ensure battery recycling and avoid lead contamination IDCOL together with all POs and battery manufacturers implemented a system that guarantees clients above informal market prices for broken batteries once they hand batteries over to POs when they buy a new one[23]. POs have the responsibility to collect and to transport batteries to battery manufacturers for recycling (Husain, 2010) and batteries have to be delivered with acid, otherwise clients are not paid for the battery (Islam, 2010a). This is a promising mechanism to ensure battery recycling and data on battery management and recycling should be collected in order to evaluate whether the mechanism is target-aimed.

The credit risk, which was analysed in order to evaluate the financial sustainability of the programme, a crucial pre-condition to contribute to sustainable development as such, is decidedly high with an average PAR30 of 11%. And indeed, micro-energy loans involve a higher risk than microloans, which can be concluded from comparing the portfolio quality of those institutions offering both, microloans as well as other MF services and micro-energy loans. However, the low portfolio quality is currently not threatening the programme (see also Wiese et al., 2009a), but individual POs with a PAR30 of 15% or more are a serious concern. As the PAR30 does not give any information about the actual portfolio loss, the collection efficiency of POs, the indicator predominantly used by IDCOL, is consulted at this point to get an even better idea of credit risk. Currently, about 10% of unit offices have an overall monthly collection efficiency, i.e. the sum of monthly payments and overdue payments divided by the sum of regular monthly due payments and past overdue payments (IDCOL, 2008a), below 50% and thus do not get any loans or grants from IDCOL for installations to incentivize collection (Pavel, 2010). Yet, the overall collection efficiency of POs throughout the whole programme duration is high ranging from 89% to 100% and with an average of 97% (IDCOL, 2010i). This indicates that POs do collect but they collect late and this can threaten financial sustainability once installation numbers stagnate or decrease. Steidl (2010) suggests that the focus on installation instead of risk management could be related to the business model, i.e. the one-hand approach combining extension of credit and SHS installation. While this argumentation is in line with the literature pointing out that a strong partnership between MFIs and a

23 Informal market prices are approx. BDT 500 (Islam, 2010)

supplier is key, there is no project following the two-hand approach that reached a comparable scale.

The technical performance of the SHS under the programme is key for its long-term success. Only 6.5% of inspected systems had technical problems requiring immediate action. But more than half of the systems showed deficiencies that need attention, such as long wiring or the use of below standard quality equipment. Severe problems due to client misbehaviour are moderate and seem to be more common among new systems. What puts a serious risk to the sustainability of the programme is that the quality of installations is declining showing that staff and customer training must be improved.

5.5 Considerations on Replicability

In order to serve as a benchmark for other projects, it is important to clearly outline and discuss factors of success and replicable elements of the programme. Independent from registration under the CDM, the project design serves as a very good example for rural off-grid electrification. Once the project is registered under the CDM, its documentation will also give orientation for other programmes intending to utilize the carbon market. And although the institutional choice was not originally made with respect to the carbon market, the analysis showed that CDM-related activities assimilate very well into the project design, so that replication of core elements is a promising approach.

The ISEP is expected to be one of the most successful SHS programmes in the world (Wiese & Schacht, 2010) and represents more than 99% of SHS installed in Bangladesh today (Sharif, 2010a). Experts outline the following key success factors. First and foremost, the financial mechanism and the possibility for payment by monthly instalments is key for the success of the programme. Without this mechanism there would be no comparable SHS industry in Bangladesh (Khaleq-uz-zaman, 2010; Pavel, 2010; Quddus, 2010; Rahman, 2010). Only 3.66% of SHS are purchased without the use of the credit facility (Islam, 2010a), which demonstrates that programme scale would be significantly lower without micro-energy loans. Another important aspect to ensure affordability is the grant structure bringing down high up-front costs (Steidl, 2010) and which should be in place until a sustainable market is built up. Micro-energy loans and subsidies benefiting end-consumers directly are social factors, which are key to programme success. For programmes considering carbon finance as a source of financial resources, it must be ensured that further funds are available as carbon revenue

is not sufficient to ensure significant price reductions, which are important to include poor target groups.

The client network and the infrastructure ensuring proximity to clients is another success factor (Gomm, 2010) and here the programme greatly benefits from the existing MF network in Bangladesh (Sadeque, 2010). POs are the key players in the programme as they implement and promote the technology (Quddus, 2010) and IDCOL only selects POs having a regional or national infrastructure in place and in addition experience in MF (Sharif, 2010). Sadeque (2010) emphasises that the MF infrastructure is difficult to replicate and must rather be in place before a MEL programme is implemented. Accordingly, an existing, well-functioning rural MF network is key to ensure a significant outreach of the project. Outreach, in turn, is essential to ensure that CDM transaction costs can be spread over a large number of SHS avoiding further reductions of carbon revenue contributions.

In addition, a strong and dedicated financial institution like IDCOL having the capacity to supervise and monitor the programme and to provide financial facilities for POs is an integral part of the ISEP (Quddus, 2010; Sadeque, 2010; Steidl, 2010). This particular institutional set-up with a financing institution and a network of MFIs also ensures that SHS dissemination and carbon monitoring can be achieved at marginal additional cost. The provision of soft loans is especially crucial for small MFIs as pre-financing of SHS is much more difficult for them (Rabbi, 2010; Wiese, 2010). In the ISEP it can be seen that those POs driving the programme are large, established organizations, such as Grameen Shakti, BRAC Foundation and RSF. POs indicate that it can take months from the purchase of a SHS to the receipt of soft loans and grants, which is a challenge for smaller POs (Rabbi, 2010; Ullah, 2010). Accordingly, it could be necessary to adjust this part of the ISEP for other programmes and instead of providing grants and credits ex post, upfront finance should be granted for MFIs struggling to pre-finance the SHS costs.

To ensure quality and long lifetimes of equipment two institutional aspects are of major importance. Free and proper maintenance provided to the clients within the repayment period and the specification of technical standards (Khaleq-uz-zaman, 2010; Rabbi, 2010; Rahman, 2010; Sharif, 2010; Steidl, 2010). According to Gomm (2010) quality is even more important than price, as poor people cannot afford to buy products of minor quality. An additional advantage of free maintenance is that it also contributes to client

education, which is integral to avoid application errors and complaints (S. Islam, 2010; Rabbi, 2010).

Last but not least, market and supply chain development, which was successfully promoted in Bangladesh, is an additional factor facilitating programme success (Quddus, 2010) and economic development. Sharif (2010) links the successful supply chain development to the *"business proposition"* of the programme. Every step in the value chain is expected to be profitable. If a national supply chain cannot be developed, political support for the programme is key as import tariffs for panels and equipment must be as low as possible.

Certainly, the success of the project is also due to Bangladesh's high population density and the infrastructure in place (Drenkard, 2010; Sadeque, 2010). Similar preconditions are rare in LDCs, but for the success of a project it is important that the population structure fits the programme design (Drenkard, 2010). In many African LDCs for example, not only the MF industry is less well established compared to Bangladesh, which is among the countries with the most MF customers (Karlan & Morduch, 2010), but also sparsely populated areas impede building up a maintenance infrastructure ensuring proximity to the client (Bahnsen, 2010; Gomez, 2010; Sharif, 2010; Wiese, 2010). Just to give a comparison, while Bangladesh has a population density of more than 1,100 inhabitants per km^2, Ethiopia has only 70 and Malawi 132 inhabitants per km^2 (Worldatlas, 2010). Taking this into account programme coordination, provision of maintenance and accurate monitoring is more difficult and costly in countries where the infrastructure is less developed. An interesting approach of some POs is the training of women in the communities, who then provide maintenance services to SHS clients (Kamal, 2010). This not only creates jobs but also circumvents the necessity to have a branch office in proximity to every community and reduces infrastructure requirements.

For the contribution of carbon finance it should be kept in mind that the SHS programme in Bangladesh is the most successful of its kind whereas other SHS programmes stay well below one million systems. For example, the number of SHS installed under China's Renewable Energy Project was 400,000 and under Sri Lanka's Renewable Energy for Rural Economic Development Project, which also builds on MFI infrastructure, only 70,000 in the period from 2002 - 2006 (REN21, 2010). This, of course, will also impact carbon revenues from a PoA project as transaction costs are predominantly reduced when economies of scale can be utilized. However, it should be kept in mind that a PoA has a duration of 28 years providing the facility to add projects

over time and that a programme can be multinational. Furthermore, the ISEP programme was already in place when the PoA was designed and some POs already had experience with MEL. Independent of the additionality issue, this means that upscaling for this PoA will be much easier than for programmes in other countries starting from scratch. However, building projects on the success factors outlined above without disregarding spatial differences and necessary design adjustments is a promising approach for both MEL and CDM projects.

6 Conclusion & Recommendations

This thesis analyses how the combination of micro- and carbon finance can overcome barriers to rural electrification and RE. In particular, the focus is on the opportunities of MEL projects under the programmatic CDM and the barriers projects are facing. On the basis of a MCA of the IDCOL Solar Energy Programme in Bangladesh, the thesis studies how carbon revenues can improve the economic viability of a MEL project and how such projects promote sustainable rural development.

To begin with, it is found that the combination of carbon and microfinance is mutually beneficial. MEL projects can benefit from additional revenue streams through the CDM. In return, the PoA provides the right framework to register dispersed rural electrification projects under the CDM and can benefit from the well-established client network and local infrastructure of MFIs, providing a perfect dissemination channel for micro-energy systems. The experience of MFIs in monitoring dispersed micro-activities, which is critical for credit risk and environmental integrity of carbon projects, can reduce CDM transaction costs significantly, as monitoring procedures and databases are in place and as loan repayment can partly serve as a substitute for on-site monitoring.

The combination of the two financing mechanisms addresses major barriers to rural electrification, most importantly the lack of information, infrastructure and access to credit for end-users as well as high upfront costs of energy systems. As the local infrastructure of MFIs can facilitate PoA implementation, it can promote rural electrification by creating awareness of RE technologies and by providing the dissemination network. Micro-energy loans overcome the lack of access to credit and spread high initial upfront costs over a longer period, which enhances affordability of micro-energy systems. Depending on the magnitude of carbon finance, costs of energy systems can be further reduced. As an alternative, carbon revenues can be utilized to co-finance necessary organizational resources to manage micro-energy loans and CDM

projects and thus address the cost barrier for energy providers, in this case MFIs. Furthermore, carbon finance reduces environmental externalities by rewarding low-carbon technologies, which can furthermore improve the economic viability of clean energy projects.

Although the combination of carbon and microfinance is promising barriers to registration under the CDM and to rural electrification remain. The PoA approach was aimed at reducing complexity and high transaction costs, but these two barriers continue to be the major obstacles. Moreover, revenue streams of carbon and microfinance are not well matched. CDM revenues are generated in the project operation phase and delays in the CDM project cycle prevent timely revenue generation, whereas high upfront costs are the major barrier to implementing micro-energy projects. Thus, cost barriers for MFIs are not limited to CDM transaction costs. While ERPAs and the new loan scheme introduced under the UNFCCC only address CDM-related upfront costs, other financial resources must be available to pre-finance the project as such – the CDM, originally designed as a co-financing mechanism, does not address resource limitations adequately, as it does not offer any facilities to get necessary seed-funding for rural electrification projects.

Additionally, the financial contribution of the CDM during the project operation phase is marginal at current CER price levels. In the IDCOL Solar Energy Programme net present values of carbon finance account for only up to 6.4% of upfront costs of a 50 Wp SHS. However, carbon revenues can finance staff and customer training, which are of major importance to ensure technical performance, or co-finance price reductions of SHS and necessary spare parts. A pro-poor approach would be to reduce prices for small SHS in particular in order to reach poorer target groups.

Whether micro-energy projects promote sustainable development, is addressed at two levels: First, programme sustainability, which is crucial for the longevity of the programme, and second the impact on social and environmental sustainability. The programme achieves energy cost reductions for rural households with a significant IRR of almost 38% and improved energy services, which create further benefits, such as improved health and better educational outcomes, both not quantified in this thesis. CO_2 emission reductions are marginal on a global scale but the goal to promote development without further environmental degradation is certainly achieved. However, the credit risk and technical performance of the analysed project are not optimal, as training and risk management lag behind current growth rates. The results demonstrate the

importance of maintenance services and that energy loans are exposed to additional technical risk factors compared to business microloans.

In summary, the combination of MEL and carbon finance is a promising approach to promote rural electrification. At current CER price levels, however, the CDM does not overcome financial barriers, which not only questions the feasibility of this complex approach for MFIs but also makes additionality argumentations for projects difficult. Admittedly, the CDM was not designed as a mechanism for energy poverty alleviation, but with the objective to co-finance sustainable development projects. And as these projects in particular are dependent on additional financial resources, CDM revenues should offer an opportunity for co-financing.

The author recommends that PoA regulation should be further adapted to rural electrification and other micro-energy project realities by reducing complexity and by allowing for divergent multi-technology CPAs. Carbon project developers and funds should provide capacity building and technical assistance to MFIs planning to diversify their product portfolio. In turn, MFIs getting involved in carbon markets should have a significant outreach or – in most cases the best option – build a network with other MFIs to ensure a fast expansion of the PoA project. For most MFIs the best option will be not to coordinate but to participate in a PoA, an approach also followed by the programme in Bangladesh. What is needed to involve MFIs in the carbon market and MEL are initiatives that overcome the lack of information on carbon market opportunities and renewable energy solutions. LDCs planning to increase the number of CDM projects should identify established MFIs or other potential PoA coordinating entities that can provide a financing and a PoA framework for a network of MFIs. However, even if CER prices increase, the combination of the two financing mechanisms cannot overcome legal and regulatory barriers to rural electrification and must be accompanied by a pro-renewable energy policy framework and by other instruments promoting energy access and low-carbon development.

The results of this thesis should be substantiated by further case studies on MEL projects, preferably in other LDCs with less favourable population and infrastructure conditions than Bangladesh, and include further RE technologies suitable for rural electrification. Furthermore, data on MEL projects should be collected systematically to enable comprehensive empirical analysis on the sustainable development impact. In the ISEP in particular, the productive use of SHS should be analysed in detail and further research on possibilities for productive use of SHS should be conducted. In addition, a

more comprehensive economic analysis of the project should include the welfare benefits of SHS, such as better indoor air quality and related health benefits, quality of light and better educational outcomes, as well as opportunities for income-generating activities.

Appendix

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Appendix 23: Extracted Data from Monitoring Reports

Appendix 1: The Impact of Energy and Climate Change on MDG Achievement

<table>
<tr><th>Millennium Development Goal</th><th>Positive Impact of Modern Energy</th><th>Examples of Adverse Impacts of Climate Change</th></tr>
<tr><td>Goal 1: Eradicate Extreme Poverty and Hunger</td><td>Energy for local micro-enterprises and income generation, increasing agricultural yields, reduction of energy expenditure.</td><td>Reduction of access to water, alteration of regional food security, changes in natural systems and resources affecting economic growth.</td></tr>
<tr><td>Goal 2: Achieve Universal Primary Education</td><td>Reduction of time spent by children to collect fuel wood, lighting for reading, energy for communication and information technology.</td><td>–</td></tr>
<tr><td>Goal 3: Promote Gender Equality and Empower Women</td><td>Reduction of time spent by women to collect fuel wood, time and lighting for domestic income generation, increased safety through street lighting.</td><td>Subsistence farming and agriculture, in which women are disproportionally involved, are particularly vulnerable to climate change.</td></tr>
<tr><td>Goal 4: Reduce Child Mortality</td><td rowspan="2">Energy supply for health clinics, reduction of indoor air pollution from traditional fuels, communication for emergencies.</td><td rowspan="3">Increases in health-related mortalities and illnesses, malaria and dengue fever and other vector-borne diseases, vulnerability to water-borne, food-related and other contagious diseases.
Declining quantity and quality of drinking water and declining food production.</td></tr>
<tr><td>Goal 5: Improve Maternal Health</td></tr>
<tr><td>Goal 6: Combat HIV/AIDS, malaria and other diseases</td><td>Energy supply for health clinics, reduction of indoor air pollution from traditional fuels, communication for emergencies, cooling of vaccines and medicines.</td></tr>
<tr><td>Goal 7: Ensure Environmental Sustainability</td><td>Reduction of unsustainable use of biomass and deforestation, soil degradation, erosion and emissions.</td><td>Alteration of quality and productivity and maybe irreversible damage of natural resources and eco-systems and reduction of biodiversity.</td></tr>
<tr><td>Goal 8: Develop a Global Partnership for Development</td><td>Energy for information and communication technologies.</td><td>Degree of responsibility and vulnerability are diametrically opposed.</td></tr>
</table>

Source: Author based on UNDP (2008), Modi (2004) and Kreft et al. (2010).

Appendix 2: List of Least Developed Countries in Accordance with UN Definition[24]

Africa (33 LDCs)

1 Angola	18 Madagascar
2 Benin	19 Malawi
3 Burkina Faso	20 Mali
4 Burundi	21 Mauritania
5 Central African Republic	22 Mozambique
6 Chad	23 Niger
7 Comoros	24 Rwanda
8 Democratic Republic of the Congo	25 São Tomé and Príncipe
9 Djibouti	26 Senegal
10 Equatorial Guinea	27 Sierra Leone
11 Eritrea	28 Somalia
12 Ethiopia	29 Sudan
13 Gambia	30 Togo
14 Guinea	31 Uganda
15 Guinea-Bissau	32 United Republic of Tanzania
16 Lesotho	33 Zambia
17 Liberia	

Asia (15 LDCs)

1 Afghanistan	9 Nepal
2 Bangladesh	10 Samoa
3 Bhutan	11 Solomon Islands
4 Cambodia	12 Timor-Leste
5 Kiribati	13 Tuvalu
6 Lao People’s	14 Vanuatu
7 Maldives	15 Yemen
8 Myanmar	

Latin America and the Carribean (1 LDC)

1 Haiti	

Source: Adapted from UN (2009).

24 Least Developed Countries are defined according to the following three criteria, which all have to apply:
(1) Low-income criterion, based on a three-year average estimate of the gross-national income per capita, which has to be lower than US $ 905 for inclusion;
(2) Human Capital Status Criterion, which is based on an index including (a) nutrition, (b) health, (c) education and (d) adult literacy rate as indicators;
(3) Economic Vulnerability Criterion, based on an index including (a) population size; (b) remoteness; (c) merchandise export concentration; (d) share of agriculture, forestry and fisheries in gross domestic product; (e) homelessness owing to natural disasters; (f) instability of agricultural production; and (g) instability of exports of goods and services as indicators (UN, 2009a).

Appendix 3: Expert Interviews

Experts	Position & Company	Type of Interview
Carbon Markets		
Stephanie Ruelle	Business Developer at Orbeo	Telephone Interview
Wolfgang Sterk	Project Coordinator at Wuppertal Institute for Climate, Environment and Energy	Personal Interview
Cristof Arens	Research Fellow at Wuppertal Institute for Climate, Environment and Energy	Personal Interview
Carolyn S. Neufeld	Senior Project Manager at KfW Carbon Fund	Personal Interview
Marc André Marr	Head of Business Unit CDM/JI Management at Perspectives GmbH	Personal Interview
Lisa Hodes	General Counsel and Director, US Markets at Gold Standard Foundation	Telephone Interview
Niels Bahnsen	Director of Energy at NIRAS A/S	Personal Interview
Meinrad Bürer	Technical Director at Gold Standard Foundation	Telephone Interview
Microfinance & Energy Lending		
Michael Steidl	CEO at Micro Service Consult	Personal Interview
Jose Manuel Gomez	Consultant Micro Service Consult	Telephone Interview
Diane A. Sanford	Consultant Business Development for Micro Energy Credits (Former Counsel Voluntary Markets at EcoSecurities)	Telephone Interview
Rural Electrification		
Rafael Wiese	Head of Department Consulting at PSE AG & Manager of Bundesverband Solarwirtschaft e.V.	Personal Interview
Stefan Drenkard	Director Sustainable Energy Projects at INTEC – GOPA International Energy Consultants	Telephone Interview

Source: Author.

Appendix 4: Key Questions of Expert Interviews

Carbon Market Experts	
Topic Area 1: The Clean Development Mechanism & Programme of Activities	
1	What do you see as the most important barriers/obstacles for small-scale projects under the CDM?
2	Does the PoA overcome these obstactles?
3	Why – in general – does it take so long until projects are registered?
4	Why did only such a small number of PoAs manage to get registered yet? What is the main barrier?
5	Do you think that the PoA, in its present form, has the potential to substantially promote dispersed micro-and small-scale projects in LDCs? Why/how?
6	How can the PoA process be further simplified and where do you see the major issues for improvement in order to make the PoA a success for LDCs without putting environmental integrity at risk?
Topic Area 2: Synergies between Microfinance & the Carbon Project Cycle	
7	What do you see as the key role/responsibilities of the coordinating entity? What particular capacities/characteristics (regarding size, outreach, capacity) should it have?
8	Why are banks/MFIs in particular eligible for being a PoA coordinating entity? Which characteristics make them suitable?
9	Where in general do you see potential synergies between a MFI/bank and the CDM/PoA project cycle?
10	What are the particular challenges in monitoring of dispersed micro-activities?
11	How would you judge the opportuity to get upfront capital e.g. through an ERPA (Emission Reduction Purchase Agreement) for a PoA project?
Topic Area 3: State of the Carbon Market & Market Development	
12	How will the market develop after 2012, what do you expect?
13	What is a likely scenario for the CDM and the CDM/PoA in a post-2012 regime without a Kyoto-like successor?
Microfinance & Energy Lending Experts	
Topic Area 1: Trends in Microfinance	

1	What are the most important current trends in microfinance? How do you judge these trends?
2	How does energy lending fit into the current trends of the microfinance industry?
Topic Area 2: Barriers & Challenges to Energy Lending	
3	What are relevant barriers for the provision of energy loans from an MFI perspective?
4	Would you say, in general, that a one-hand approach (a MFI building up an energy department) or a two-hand approach (strategic partnership between MFI and energy company) is more promising?
5	Would you say that there are specific characteristics a MFI should fulfil in order to qualify for energy-lending?
Topic Area 3: Microfinance & Carbon Markets	
6	Where do you see the benefits for (a) the MFI to involve in carbon offset market activities and (b) for the carbon offset market, e.g. in terms of project types?
7	Where do you see the challenges for MFIs to integrate technical and carbon monitoring in their loan monitoring procedures?
8	How could monitoring be organized after the loan cycle is finished and what risks are related to the period after loan repayment?
Topic Area 4: Risk Management	
9	What is the main difference between business loans and housing/energy loans in terms of risk management?
10	Doas a best practive approach for a micro-energy loan cycle exist? How should it look like?
Rural Electrification Experts	
Topic Area 1: Challenges for Rural Off-Grid Electrification	
1	What are market barriers for rural off-grid electrification in general and for the electrification with renewables in particular?
2	What are critical success factors for rural electrification projects?
3	Which renewable energy technologies – from your perspective – are most appropriate for energy needs of the rural population in developing countries?
Topic Area 2: Emission Reductions & Carbon Markets	

4	Which technologies – from your perspective – are most appropriate from a carbon market perspective (in terms of emission reductions, cost efficiency, potential carbon revenue)?
5	In the long-term, do you see any chances that carbon finance can substitute or contribute significantly to other sources of subsidies/development aid for rural electrification?
Topic Area 3: Future Development	
6	What are trends the trends in rural electrification from a technology perspective?
7	What can be expected for the price development of renewable energy systems (solar PV in particular) for rural electrification?

Source: Author.

Appendix 5: Stakeholder Interviews

Experts	Position & Company	Type of Interview
Infrastructure Development Company Limited (IDCOL)		
S.M. Fomanul Islam	Director, Legal Affairs and Company Secretary	Personal Interview & Email Correspondence
Islam Sharif	Executive Director & CEO	Personal Interview
Nazmul Haque	Director Investment	Personal Interview
Farzana Husain	Investment Officer (Technical)	Personal Interview
Farhan Reza	Senior Loan Officer	Personal Interview & Email Correspondence
Enamul Karim Pavel	Director Loans	Personal Interview
Donors		
Zubair Sadeque	Financial Analyst South East Asia Sustainable Development at The World Bank	Personal Interview
Tazmilur Rahman	Local Energy Expert at Kreditanstalt für Wiederaufbau (KfW)	Personal Interview
Erich Otto Gomm	Programme Coordinator Sustainable Energy for Development (SED) at Gesellschaft für Technische Zusammenarbeit (GTZ)	Personal Interview
M. Khaleq-zu-zaman	Senior Advisor Sustainable Energy for Development (SED) at Gesellschaft für Technische Zusammenarbeit (GTZ)	Personal Interview
Partner Organizations		
Dipal Barua	Founder & Chairman of Bright Green Energy Foundation (Founding Manager of Grameen Shakti and Co-Founder & Former Deputy Managing Director of Grameen Bank)	Personal Interview
Ruhul Quddus	CEO at Rural Service Foundation (RSF)	Personal Interview
Kazi Mahmud Ullah	Deputy General Manager at Rural Service Foundation (RSF)	Personal Interview
Fazley Rabbi	Senior Manager at Grameen Shakti	Personal Interview
Dr. Shahidun Islam	Consultant and CDM Responsible at Grameen Shakti	Personal Interview
Energy Experts		
James Ford	Country Director Bangladesh at NRECA International Programs	Personal Interview
Svend Olling	Ambassador at the Danish Embassy Bangladesh	Personal Interview

Source: Author.

Appendix 6: Key Questions of Stakeholder Interviews

Infrastructure Development Company Limited (IDCOL) [25]	
Topic Area 1: IDCOL Solar Energy Programme	
1	The IDCOL Solar Energy Programme is said to be one of the most successful SHS implementation programmes – what in your opinion makes the programme so successful?
2	What can other developing countries learn from the programme?
Topic Area 2: IDCOL Solar Energy Programme & Carbon Finance	
3	Where do you see the role of carbon finance for SHS and the IDCOL Solar Energy Programme in particular?
4	The project is currently in the validation phase of the CDM project cycle: What are the obstacles the project faces in the CDM project cycle?
5	How will the programme be continued if it is not registered under the CDM?
6	How is CDM-related monitoring organized by IDCOL?
7	How are clients without a maintenance contracts monitored for the CDM and how is ensured that SHS are still operational after repayment?
Topic Area 3: Performance & Risk Management	
8	How would you describe the technical performance of the SHS in the programme? What are common technical problems?
9	What kind of capacity building and training do you do for the POs (e.g. for risk management, technical know how) and how often?
10	What are incentives for POs to keep PAR and delinquency rates as well as installation failures low?
Donors	
Topic Area 1: Rural Electrification in Bangladesh	
1	What are the major challenges for rural electrification in Bangladesh?

[25] The information provided by IDCOL clearly exceeds the information requested by the questions presented in this table. Only key qualitative questions are presented here.

2	What do you see as the role of SHS in rural electrification in Bangladesh?
3	What are particular challenges for RE with SHS in Bangladesh?
Topic Area 2: IDCOL Solar Energy Programme	
4	The IDCOL Solar Energy Programme is said to be one of the most successful SHS implementation programmes – what in your opinion makes the programme so successful?
5	What can other developing countries learn from the programme?
6	Micro-Energy Lending is still a rather young approach to promote rural electrification – what are the risks involved in this approach?
7	How do you think could risk management of IDCOL and the POs be improved?
Topic Area 3: IDCOL Solar Energy Programme & Carbon Finance	
8	The project is currently in the validation phase of the CDM project cycle: What do you think are the obstacles the project faces in the CDM project cycle?
9	What do you think would happen if the project would not be accepted by the CDM EB – would there be a significantly lower electrification rate with SHS?
10	Where do you see the role of carbon finance for rural electrification in general and for SHS in particular?
Partner Organization	
Topic Area 1: Rural Electrification in Bangladesh	
1	What are the major challenges for rural electrification in Bangladesh?
2	What are particular challenges for RE with SHS in Bangladesh?
Topic Area 2: Micro-Energy Loan Portfolio	
3	How many SHS clients do you have and what is the most popular SHS (in terms of size) in your portfolio?
4	How many of those are business clients, how many are households (approximately)?

5	What are the loan conditions?
6	Do you see a difference in risk between income-generating microloans and consumer loans, such as energy loans?
7	How is credit risk-management organized at your organization?
8	Could you outline the additional effort (know how, time and cost expenditure) related to SHS loan monitoring compared to normal loan monitoring?
Topic Area 3: Micro-Energy Lending & Carbon Markets	
9	Where do you see the role of carbon finance for rural electrification with SHS?
10	What will you use carbon revenues for?
11	Do you see any problem in the difference between the loan period and the CDM credit period (3 versus 7 years)?
Topic Area 4: IDCOL Solar Energy Programme	
12	Why did you choose to join the IDCOL Solar Energy Programme? What are advantageous for your organization?
Energy Experts	
Topic Area: Rural Electrification in Bangladesh & Impact of Carbon Finance	
1	What are the major challenges for rural electrification in Bangladesh?
2	What do you see as the role of SHS in rural electrification in Bangladesh?
3	Where do you see the role of carbon finance and the CDM for rural electrification in general and for SHS in particular?

Source: Author.

Appendix 7: SHS Client Questionnaire

Case Study IDCOL Solar Energy Programme

Background Information

Name of Client: ____________________ **Adress** ____________________
(Street, Area, Village)

Household [ ] **Business** [ ]

Occupation Head of Household ____________ **Type of Business** ____________________

No of household members ________ **No of Customers** ____________________
(per day)

Average income of business or household ____________________
(Taka/month)

SHS Provider/MFI ____________ **Unit Office:** ____________
(Name of IDCOL PO)

Size of SHS ____________
(Wp)

Date of Intsallation ____________
(month/year)

Use of SHS

Main intention to buy a SHS: ____________________

Appliances used:		**Time of Usage:**		**Purpose of Usage:** e.g. business/household activities	
No of Lamps	[ ]	hours/day	______	Light used for:	____________
No of TVs	[ ]	hours/day	______	TV used for:	____________
No of Radios	[ ]	hours/day	______	Radio used for:	____________
No of Phones charged	[ ]	hours/day	______	Phone used for:	____________

Others: ____________________
Time of usage: ____________________
Purpose of usage: ____________________

In case of income generating activities:
Average Income before SHS installation ____________
(Taka/month)

What are the advantages/disadvantes of the SHS compared to your prior use of energy:

____

____

Cost & Technical Performance of SHS

Total Loan Amount for SHS: ____________ **Loan Tenure:** ____________
(Taka) (years)

Down Payment at unit office: ____________
(Taka)

Monthly Loan Installment: ____________ **Interest Rate:** ______
(Taka) %

Do you have a Maintenance Agreement with your SHS provider: [ ]

Cost/Year for Maintenance Services: ____________
(Taka)

Did you have any technical problems with the SHS, which ones:

____

____

Was there a need to repair any part of the system, which part:

Part: ________ Price of Repair: ________

Part: ________ Price of Repair: ________

Part: ________ Price of Repair: ________

Did you have to replace any spare parts until now, which ones:

Battery:	☐	How often:	________	Price:	________
Charge Controller:	☐	How often:	________	Price:	________
Lamps:	☐	How often:	________	Price:	________
Switch/cable:	☐	How often:	________	Price:	________
Others:	________	How often:	________	Price:	________

Prior Energy Consumption & Expenditure

What kinds of energy did you use before the installation of the SHS:

Kerosene ☐

Car battery ☐

Others: ____

What on average did you consume and pay for:

Kerosene consumption	________ (liter/month)	Kerosene price	________ (taka/month)
Car battery charging	________ (times/months)	Chrarging price	________ (taka/charge)

Others: ____

____

Did your energy expenditure:

Increase ☐

Decrease ☐

Remain constant ☐

Don't know ☐

Other Sources of Energy

Does your SHS provide you with enough energy for the appliances used:

Yes ☐

No ☐

Which other forms of energy do you use additionally and how often:

Kerosene ☐ How often: ________________ (daily, weekly, monthly, less than once a month)

Car battery ☐ How often: ________________ (daily, weekly, monthly, less than once a month)

Others: ______________________

Source: Author.

Appendix 8: CDM Transaction Cost Components

Transaction Cost Components	**Costs incurred by project proponents**	**Relation to Project Size**
Negotiation Cost	Includes those costs incurred in the preparation of the project design document that also documents assignment and scheduling of benefits over the project time period. It also includes public consultation with key stakeholders.	Degressive
Project Documentation Cost	Development of a baseline and monitoring plan.	Fixed (Degressive for CPA documentation)
Approval Costs	Costs of authorization from host country.	Proportional
Validation Costs	Review and revision of project design document by operational entity.	Fixed
Registration Costs (LDCs are exempted)	Registration by CDM Executive Board.	Slightly degressive
Monitoring Costs	Costs to collect data.	Fixed
Verification Costs	Cost to hire an operational entity and to report to the CDM Executive Board.	Degressive
Certification Costs (LDCs are exempted)	Issuance of CERs by UNFCCC Executive Board.	Degressive
Enforcement Costs	Includes costs of administrative and legal measures incurred in the event of departure from the agreed transaction.	Proportional

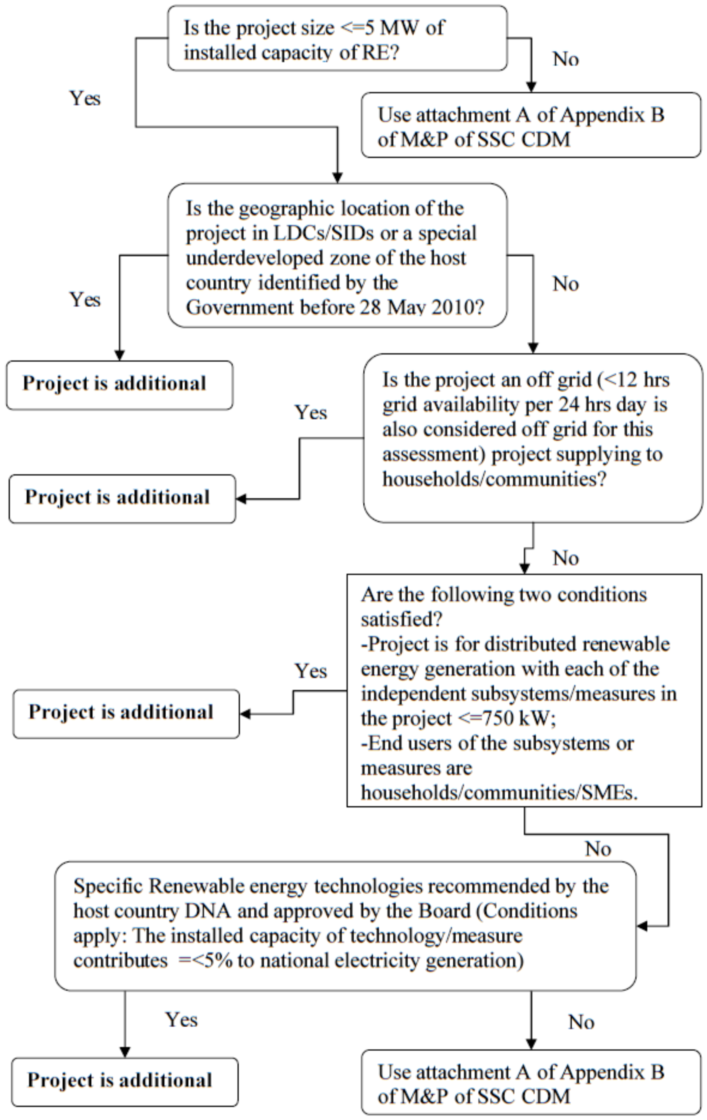
Source: Revised from Michaelowa & Jotzo (2005).

Appendix 9: Technology Portfolio for Rural Off-Grid Areas

Technology	Application	Substituted Energy Sources	PoAs
Small-scale biomass (gasifier, briquettes)	Lighting, Communications (TV, radio, mobile phone) and other small electric needs.	Lighting: Candles, kerosene, batteries charged from grid or diesel. Communications: Batteries charged from grid or diesel.	1
Solar Home System			1
Hydropower (pico-, micro-, small-scale)			5
Solar PV Lanterns	Lighting.	Candles, kerosene, batteries charged from grid or diesel.	0
Biogas from household-scale digester	Lighting, Communications, Cooking.	Cooking: Burning wood, dung, or straw in open fire.	0
Solar Water Heating	Heating.	Open Fire from wood, dung, and straw.	6
Solar PV Pumps	Water Pumping (agriculture and drinking water).	Diesel pumps and generators.	0
Improved Cooking Stoves	Cooking.	Burning wood, dung, or straw in open fire.	5
Solar Cookers	Cooking.	Burning wood, dung, or straw in open fire.	0
Improved Heating Stoves	Heating.	Open Fire from wood, dung, and straw.	0

Source: Author based on REN21 (2010) and UNEP Risoe Centre (2010). Note: PoAs indicates the number of projects in the current PoA pipeline.

Appendix 10: Additionality Test for VSSC RE Projects



Source: Arens (2010a).

Appendix 11: Post-2012 Uncertainty and Market Development

The post-2012 uncertainty might slow down the development of PoAs and hamper learning and further improvement. A Kyoto-like agreement for the period after 2012 does yet not exist and negotiations at the last COPs demonstrated the difficulties to agree upon climate change mitigation as a global public good (Martinez-Alier et al., 2010). For the whole market a further decrease in volume and higher price volatility is very likely (Kossoy & Ambrosi, 2010) and the high degree of uncertainty distracts private investors, especially those not targeting the EU market (Neufeld, 2010). This is probably the most serious impediment for market growth. But the effect of the unclear regulatory and demand situation might be limited for micro-energy projects in LDCs. In the EU ETS, the *"engine of the carbon market"*(Kossoy & Ambrosi, 2010), CERs from LDCs can be traded between 2013 and 2020 independent of a follow-up agreement and even when projects are registered after 2012 (EU, 2009; Heeren & Karcher, 2010). Accordingly, at least until 2020 European demand is guaranteed and a reliable driver of CER demand – also in the absence of a Kyoto-like successor (Bahnsen, 2010). Moreover, qualitative import restrictions for CERs will require higher sustainability standards and EU member countries are compelled to contribute to a more balanced geographic distribution of CDM projects after 2012 (EU, 2009). Thus, the EU ETS could also be a main driver of the PoA after 2012 (Neufeld, 2010) and the demand for high-quality emission reductions with sustainable development co-benefits, and thus for CERs from micro-energy projects, could increase.

In the long or medium-term, experts assume that further market fragmentation, i.e. a number of regional schemes comparable to the EU ETS might be established in the absence of an international agreement and it remains to be seen what role CERs play in different regional schemes (Arens, 2010; Marr, 2010; Neufeld, 2010; Ruelle, 2010). Different quality levels and requirements for emission reductions and the total exclusion of CERs from individual ETS could further fragment and marginalize the CDM market (Arens, 2010). But by and large carbon market experts do assume the CDM and CERs to play a role in the future (Bahnsen, 2010; Hodes, 2010; Marr, 2010; Neufeld, 2010; Ruelle, 2010; Sanford, 2010). Developing countries want CDM projects and industrialized countries want CERs (Sterk, 2010). And most importantly, the recent COP16 in Cancun agreed that *"the project-based mechanisms under the Kyoto Protocol shall continue to be available to Annex I Parties as means to reach to meet their quantified emission limitation and reduction objectives"* (UNFCCC, 2010g).

All regulatory uncertainty around the CDM aside, it must be pointed out that the CDM can only be a medium term solution when climate change mitigation is taken seriously (Sterk, 2010). To achieve IPCC recommendations offsetting is no alternative to emission reductions (Bahnsen, 2010). However, the CDM has an important role to contribute to low-emission growth in developing countries and *"there is a whole community that is looking for survival"* (Bahnsen, 2010). In this regard, it is also discussed how the CDM could create net environmental benefits, for example by very conservative baselines or by discounting emission reductions generated (Sterk, 2010).

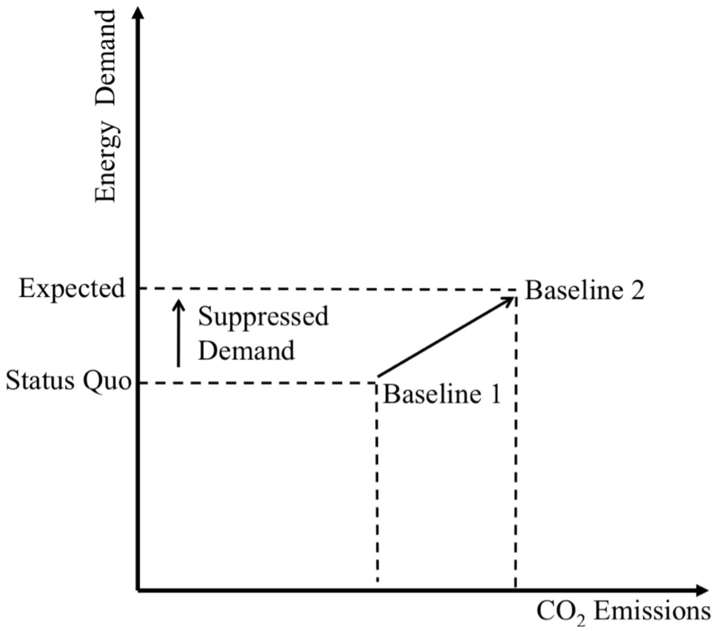
Appendix 12: Reducing CDM Complexity through Standardization

One measure currently under discussion to reduce complexity and thus also transaction costs is standardization (Bahnsen, 2010; Marr, 2010; Stehr, 2010; Sterk, 2010). Certainly, in order to ensure environmental integrity an offsetting mechanism must fulfil certain standards and procedures but when the explicit goal is to include LDCs and emission reduction potentials on the demand-side standardizations are one option to ease utilization of the CDM (Bahnsen, 2010; Marr, 2010; Stehr, 2010). In addition, standardization serves the goal of higher objectivity in baseline calculations (Sterk, 2010). A particular example is the standardization of baselines by allowing the use of standard values for kerosene replacement by SHS circumventing cost-intensive baseline surveys on kerosene consumption. Standard values could build on experience from other regions with comparable energy patterns (Marr, 2010a). Marr (2010) points out that optimization of methodologies would make it much easier to apply PoAs, especially because methodologies used under the PoA have not been used regularly for stand-alone CDM projects. The challenge here is to introduce standard values without putting environmental integrity and additionality at risk, i.e. standard values must be conservative and ensure that calculated baselines do not exceed actual emission reductions (Arens, 2010; Bahnsen, 2010; Marr, 2010).

Appendix 13: Increasing Baselines with Suppressed Demand

The decisive factor for the number of CERs generated and thus also for carbon revenues is the baseline calculation, i.e. avoided CO_2 emissions. Conservative baseline calculations generate less carbon revenue and do thus contribute less to overcoming financial barriers. According to Bahnsen (2010) pro-poor baseline calculations should include suppressed demand and should thus not based on current or historical energy consumption but on "*anticipated future demand"* (Bahnsen, 2010) that would realistically occur without income constraints. Suppressed demand can be defined as an inadequate *"level*[] *of access to energy services before any CDM intervention … because of income constraints and thus* [does] *not reflect the real demand for energy services by energy poor households"*(Thorne et al., 2006). In this discussion, there is certainly a challenge between pro-poor and pro-environment baseline calculations but incorporating suppressed demand could – without inflating emission reductions (Bahnsen, 2010) – make the CDM more attractive for pro-poor energy projects, especially in LDCs where income and energy supply are constrained. How suppressed demand increases baseline calculations is demonstrated in the figure below.

Appendix 14: Suppressed Demand



Source: Author.

Appendix 15: Detailed Assumptions for Carbon Finance Contribution

Applied Rates	Value	Explanation/Assumptions	Source
Discount Rate 1	10.00%	Discount rate applied for other CDM Case Studies.	Hayashi et al. (Hayashi et al., 2010).
Discount Rate 2	6.35%	Interest Rate of Deposits paid by Commercial Bank.	Central Bank of Bangladesh (2010a), compare Mondal (2010).
Exchange Rate EUR/USD	1.3155	Prices in EUR are converted into USD.	ECB (2010).
CDM Cost Components	**US$ (nominal)**		
Project Preparation Cost (PIN, PoA-DD, CPA-DD, validation)	200,000.00	Including project assessment and review, preparation or review of Project Documents and CDM Operation Plan, Validation of the CPA.	World Bank (2007)
CDM-Transaction Costs for 3 consecutive years	100,000.00	Kyoto Protocol and other costs for three years (incl. monitoring, verification and certification, EB communication, revision or review of baseline, extension of CPA crediting period, supervision of project, revision or reproduction of any project documents required by DOE or CDM EB). No additional costs are expected to occur in the first three years.	World Bank (2007)
Monitoring	3,000.00	Annual payments to cover statistical significant sample size. Marginal and fixed as the sample size is expected to be the same and monitoring is integrated into existing business.	Compare with case studies in Hayashi et al. (2010).
Validation/Inclusion (CPA-DD, DOE fee).	15,000.00	CPA-DD preparation can be based on generic CPA-DD and prior documents. DOE fees predominanlty account for costs. Costs accrue in years where a CPA is added (2010 - 2014).	Compare with case studies in Hayashi et al. (2010).
Verification	15,000.00	Verification of CPAs by DOE. Costs accrue every year.	Compare with case studies in Hayashi et al. (2010).

Renewal of Crediting Period	15,000.00	Requires an update of the PoA-DD and the respected CPA-DD in accordance with the latest approved version of the applied baseline and monitoring methodology. Updated documents must be validated and confirmed by a DOE. Costs accrue when any credit periods are renewed. If the methodology changed significantly costs are likely to be higher - at least for the first renewal.	CDM Rulebook (2010b).
Carbon Revenue			
Scenario 1 CER Price	11.84	Price of €9/CER based on World Bank ERPA converted into USD[26].	Haque (2010).
Scenario 2 CER Price after 2012	20.00	Small renewable energy and energy efficiency projects often get a premium price, and solar in particular.	Chaurey & Kandpal (2009) and Kossoy (2010).
CER/SHS	0.24	Author's calculations based on emission reductions of tCO_2 14.571 from 59.592 SHS giving an average emission reduction per System of kg 244,5 CO_2/year and 1 CER = 1 tCO_2.	IDCOL (2010a).
CER/small SHS ≤ 30 Wp	0.11	Author's calculations based on baseline emissions. Small SHS refers to SHS units ≤ 30 Wp.	Author's calculations based on IDCOL (2010c).
CPAs/Installations	**No of SHS**		
CPA 1: 2007-2008	59,592	According to CPA-DD.	IDCOL (2010a).
CPA 2	106,254	Grameen Shakti 2007-2008 Installations.	IDCOL (2010c).
CPA 3[27]	167,627	Total 2009 Installations.	IDCOL (2010a).
CPA 4	308,754	Expected 2010 Installations.	IDCOL (2010c).
CPA 5	364,996	Expected 2011 Installations based on average installation rate of 30.416 systems per month (calculated as the average of the last 6 months).	Author's calculations based on IDCOL (2010c).
CPA 6	364,996	Expected 2012 Installations based on average installation rate of 30.416 systems per month (calculated as the average of the last 6 months).	Author's calculations based on IDCOL (2010c).

[26] The World Bank ERPA guarantees the purchase of all emission reductions until 2012 at a price of €9/CER. There is an option until 2015 and prices have to be negotiated (Haque, 2010). However, the same price is applied throughout the whole crediting period as €9/CER is used by other studies (Satoguina, 2006) and the average price of fixed-priced ERPAs (Kossoy & Ambrosi, 2010).

[27] CPAs are calculated based on yearly installations. In order to comply with the CDM small-scale threshold a CPA should not exceed MW 15 (approximately 300,000 SHS). This would slightly increase the number of CPAs.

CPA 7	364,996	Expected 2013 Installations based on average installation rate of 30.416 systems per month (calculated as the average of the last 6 months).	Author's calculations based on IDCOL (2010c).
CPA 8	364,996	Expected 2014 Installations based on average installation rate of 30.416 systems per month (calculated as the average of the last 6 months).	Author's calculations based on IDCOL (2010c).
Total Size of PoA	**2,102,211**		

Source: Author.

Appendix 16: Calculations for Carbon Finance Contribution (Price Scenario 1)

	Nominal	NPV_1	NPV_2
Result Total	**100,395,546.55**	**37,275,140.95**	**51,386,629.20**
Result Per SHS	**47.76**	**17.73**	**24.44**

	Cost (nominal)	Cost (PV_1)	Cost (PV_2)	Revenues (nominal)	Revenues (PV_1)	Revenues (PV_2)
Total (2010)	**825,000.00**	**422,632.84**	**515,545.03**	**101,220,546.55**	**37,697,773.79**	**51,902,174.23**
Per SHS	**0.39**	**0.20**	**0.25**	**48.15**	**17.93**	**24.69**
Year						
2011	100,000.00	90,909.09	94,029.15	172,513.35	156,830.32	162,212.84
2012	100,000.00	82,644.63	88,414.81	2,652,150.55	2,191,859.96	2,344,893.84
2013[28]	100,000.00	75,131.48	83,135.69	3,598,737.05	2,703,784.41	2,991,834.96
2014	33,000.00	22,539.44	25,796.69	4,545,323.54	3,104,517.14	3,553,160.50
2015	18,000.00	11,176.58	13,230.77	5,491,910.04	3,410,044.05	4,036,788.01
2016	18,000.00	10,160.53	12,440.78	5,491,910.04	3,100,040.04	3,795,757.42
2017	33,000.00	16,934.22	21,446.26	5,491,910.04	2,818,218.22	3,569,118.40
2018	33,000.00	15,394.74	20,165.73	5,491,910.04	2,562,016.56	3,356,011.66
2019	33,000.00	13,995.22	18,961.67	5,491,910.04	2,329,105.97	3,155,629.20
2020	33,000.00	12,722.93	17,829.49	5,491,910.04	2,117,369.06	2,967,211.29
2021	33,000.00	11,566.30	16,764.92	5,491,910.04	1,924,880.97	2,790,043.52
2022	18,000.00	5,735.35	8,598.50	5,491,910.04	1,749,891.79	2,623,454.18
2023	18,000.00	5,213.96	8,085.09	5,491,910.04	1,590,810.71	2,466,811.64
2024	33,000.00	8,689.93	13,937.63	5,491,910.04	1,446,191.56	2,319,522.00
2025	33,000.00	7,899.94	13,105.44	5,491,910.04	1,314,719.60	2,181,026.79
2026	33,000.00	7,181.76	12,322.93	5,491,910.04	1,195,199.64	2,050,800.93
2027	33,000.00	6,528.87	11,587.15	5,300,702.61	1,048,715.75	1,861,212.83
2028	33,000.00	5,935.34	10,895.30	5,012,208.39	901,489.74	1,654,833.19
2029	18,000.00	2,943.14	5,588.05	4,570,125.59	747,252.05	1,418,782.24
2030	18,000.00	2,675.59	5,254.39	3,786,346.02	562,816.21	1,105,275.17
2031	18,000.00	2,432.35	4,940.66	2,839,759.48	383,738.32	779,460.62
2032	18,000.00	2,211.23	4,645.66	1,893,172.99	232,568.68	488,613.46
2033	18,000.00	2,010.21	4,368.28	946,586.49	105,713.04	229,719.54
2034	0.00	0.00	0.00	0.00	0.00	0.00
2035[29]	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author. Note: CPA 2,3,4,5 are expected to be added in 2011 and to generate CERs from 2012 onwards. In general, CPAs are expected to be added after installation, so that CERs are generated in the next year respectively. Calculations are based on a 20 year lifetime of a SHS requiring two renewals of each CPAs crediting period.

28 According to the World Bank ERPA costs are deducted during the first three Annual Payments for CERs (World Bank, 2007), all verification, monitoring and validation costs for additional CPAs are expected to be covered by the 100,000 CDM transaction costs provided by the World Bank for the first three years.

29 As the starting date of the programme actually is in dated the 01.01.2007 the programme is expected to end after 28 years in 2035 PoA-DD. However, when the last CPA is added in 2014 no emission reductions are achieved in the last two years.

Appendix 17: Calculations for Carbon Finance Contribution (Price Scenario 2)

	Nominal	NPV_1	NPV_2
Result Total	**84,332,425.15**	**61,250,538.48**	**84,641,880.12**
Result Per SHS	**78.65**	**29.14**	**40.26**

	Cost (nominal)	Cost (PV_1)	Cost (PV_2)	Revenues (nominal)	Revenues (PV_1)	Revenues (PV_2)
Total (2010)	**825,000.00**	**422,632.84**	**515,545.03**	**166,159,802.42**	**61,673,171.32**	**85,157,425.15**
Per SHS	**0.39**	**0.20**	**0.25**	**79.04**	**29.34**	**40.51**
Year						
2011	100,000.00	90,909.09	94,029.15	172,513.35	156,830.32	162,212.84
2012	100,000.00	82,644.63	88,414.81	2,652,150.55	2,191,859.96	2,344,893.84
2013[30]	100,000.00	75,131.48	83,135.69	6,079,204.44	4,567,396.27	5,053,988.69
2014	33,000.00	22,539.44	25,796.69	7,678,235.64	5,244,338.26	6,002,213.78
2015	18,000.00	11,176.58	13,230.77	9,277,266.84	5,760,452.80	6,819,186.64
2016	18,000.00	10,160.53	12,440.78	9,277,266.84	5,236,775.27	6,412,023.17
2017	33,000.00	16,934.22	21,446.26	9,277,266.84	4,760,704.79	6,029,170.82
2018	33,000.00	15,394.74	20,165.73	9,277,266.84	4,327,913.45	5,669,178.02
2019	33,000.00	13,995.22	18,961.67	9,277,266.84	3,934,466.77	5,330,679.85
2020	33,000.00	12,722.93	17,829.49	9,277,266.84	3,576,787.98	5,012,392.90
2021	33,000.00	11,566.30	16,764.92	9,277,266.84	3,251,625.43	4,713,110.39
2022	18,000.00	5,735.35	8,598.50	9,277,266.84	2,956,023.12	4,431,697.59
2023	18,000.00	5,213.96	8,085.09	9,277,266.84	2,687,293.75	4,167,087.53
2024	33,000.00	8,689.93	13,937.63	9,277,266.84	2,442,994.31	3,918,276.95
2025	33,000.00	7,899.94	13,105.44	9,277,266.84	2,220,903.92	3,684,322.47
2026	33,000.00	7,181.76	12,322.93	9,277,266.84	2,019,003.57	3,464,337.07
2027	33,000.00	6,528.87	11,587.15	8,954,267.67	1,771,554.12	3,144,073.36
2028	33,000.00	5,935.34	10,895.30	8,466,925.78	1,522,851.03	2,795,444.39
2029	18,000.00	2,943.14	5,588.05	7,720,132.76	1,262,303.40	2,396,692.84
2030	18,000.00	2,675.59	5,254.39	6,396,124.87	950,743.21	1,867,097.72
2031	18,000.00	2,432.35	4,940.66	1,915,951.63	258,903.64	525,892.72
2032	18,000.00	2,211.23	4,645.66	3,198,062.40	392,869.09	825,395.43
2033	18,000.00	2,010.21	4,368.28	1,599,031.20	178,576.86	388,056.15
2034	0.00	0.00	0.00	0.00	0.00	0.00
2035	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author.

[30] The price of €9/CER is fixed until 2012 in the World Bank ERPA. From 2013 prices are subject to negotiation (Haque, 2010), therefore the higher price is only achieved in 2013.

Appendix 18: Data and Assumptions for Cost Savings Analysis for a 50 Wp SHS

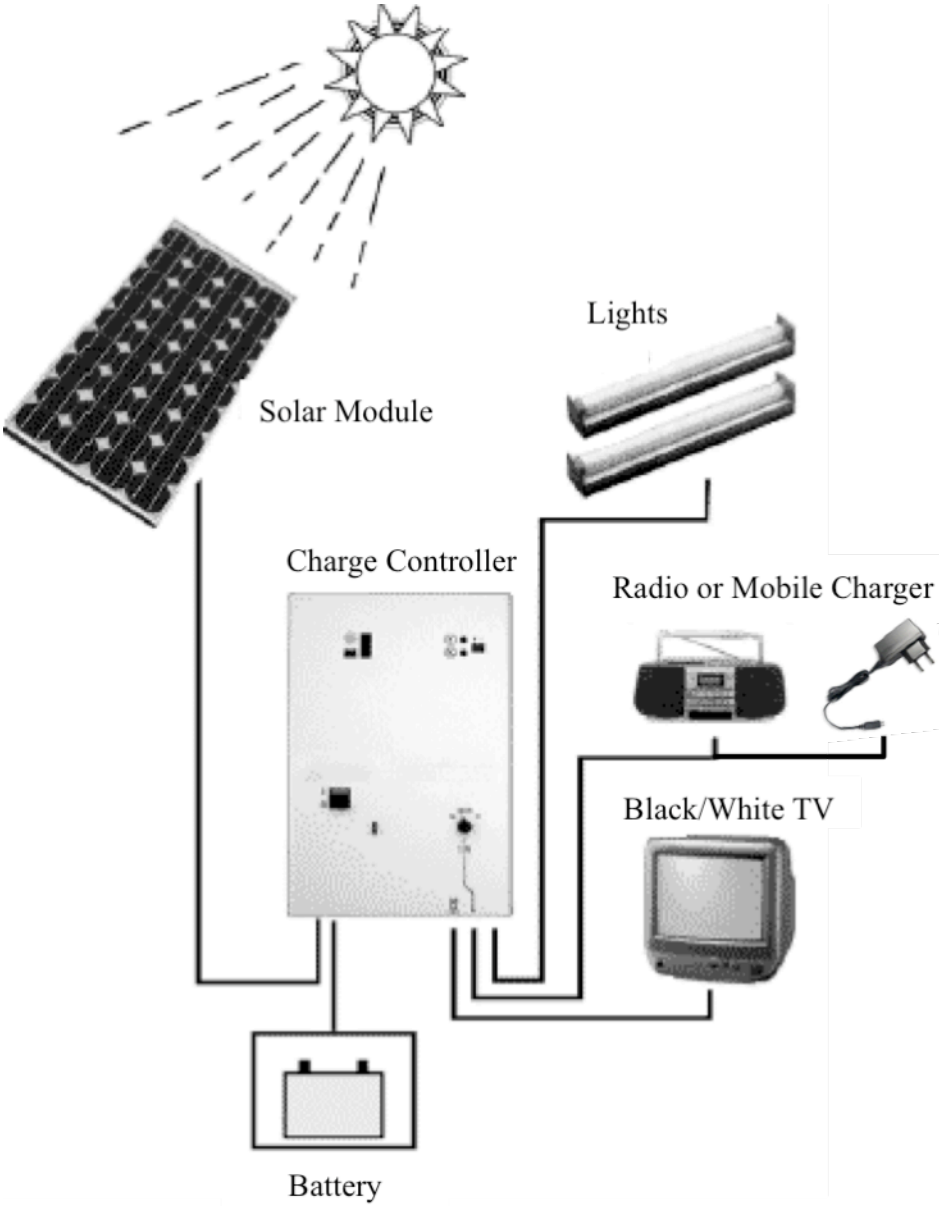
	Data	Explanation & Source
SHS life	20 Years	(Mondal, 2010; IDCOL, 2009)
1 USD (BDT)	70.48	(Central Bank of Bangladesh, 2010)
Kerosene price (BDT/litre)	45	(IDCOL, 2009; Ullah, 2010a)
Expected Price Increase (per annum)	3%	(Munasinghe, 2009)
Interest on loan (per annum)	12%	SHS clients pay 6% flat (Grameen Shakti, 2010a), which can be converted into 12% on declining balance (IDCOL, 2009).
Monthly interest rate	0.95%	Author's calculations.
Loan tenor	3 Years	(Grameen Shakti, 2010a)
Loan tenor	36 Months	
Discount Rate 1: Lending Rate for Housing Loans at Commercial Bank (per annum)	13%	(Central Bank of Bangladesh, 2010b; compare also Mondal, 2010)
Disount Rate 2: Interest Rate of Deposits paid by Commercial Bank (per annum)	6.35%	(Central Bank of Bangladesh, 2010a; compare also Mondal, 2010)
Emission Factor for Kerosene (tCO_2e/kl)	2.36	(IDCOL, 2010b)
Selling price for emission reduction (US$/$tCO_2e$)	11.84	Price based on World Bank ERPA converted into US$.
Cost of SHS and Spare Parts		
System Price (BDT)[31]	26,800	(2010).
Down payment (% of System Price)	15%	(Grameen Shakti, 2010a).
Loan Amount (BDT)	22,780	Author's calculations.
Monthly Installment (BDT)	749.96	Author's calculations. According to data collection in Bangladesh clients pay BDT 747.
Yearly Installment (BDT)	8999.58	Author's calculations.
Yearly Installment (USD)	127.69	
SHS battery (12V, 80Ah) price (BDT)	6916	Author's calculation based on battery price of BDT 8.100 (IDCOL, 2009) and price of BDT 1.480 paid for old battary (IDCOL, 2008).
SHS battery price (USD)	98.13	Batteries can also be financed by loans from POs (Ullah, 2010) but this calculation is based on cash payment.
Battery Replacement After Each	5 Year	(Mondal, 2010; IDCOL, 2009). Lifetime of battary can be up to 8 years and warranty period covers 5 years (Husain, 2010).
Charge Controller Price (BDT)	600	(IDCOL, 2009).

31 Prices are based on data from Grameen Shakti, however, POs have similar price structures and loan conditions.

Charge Controller Replacement After Each	3 Year	(IDCOL, 2009), lifetime of charge controller can be up to 4 years and warranty period covers 3 years (Husain, 2010).
Lamp Price (BDT)	350	(IDCOL, 2009).
No. of Lamps	4	(IDCOL, 2009).
Lamp Replacement After Each	3 Year	(IDCOL, 2009).
Cable/Support Structure Price (BTD)	1864	(Wiese et al., 2009),
Cable/Support Structure Replacement After Each	5 Year	(Mondal, 2010).
Voluntary Maintenance Agreement (After Repayment) Cost per Year (BDT)	300	(Wiese et al., 2007).
Avoided Costs		
Household Kerosene Consumption (litres/annum)	95.20	47,6 litre/kerosene lamp (IDCOL, 2010b).
Kupi (Kerosene Lamp) Purchase Cost (BDT)	20	(IDCOL, 2009).
Kupi replacement after each	1 Year	(IDCOL, 2009).
Purchase Cost of Kupi (USD)	0.57	
Hurricane (Kerosene Lamp) Purchase Cost (BDT)	120	(IDCOL, 2009).
No. of Kerosene Lamps	2	No of lamps replaced by SHS (IDCOL, 2010b).
Purchase cost of Hurricanes (USD)	3.41	
Hurricane replacement after each	4 Year	(Mondal, 2010).
Household Battergy Recharging Cost Savings per month (BDT)	240	Including transportation costs and based on the assumption that battery is charged 2 times per months (IDCOL, 2009).
Household Battergy Recharging Cost Savings per month (USD)	3.41	
Flate plate battery price used for TV (BDT)	5,650	(IDCOL, 2009).
Flate plate battery price used for TV (USD)	80.16	
Flat plate battery replacement after each	3 Year	(Mondal, 2010).

Source: Author.

Appendix 19: Solar Home System Components



Source: Revised from Islam (2010a).

Appendix 20: Calculations of NPV and IRR of 50 Wp SHS (Scenario 1)

Year	Annual savings from purchase of Hurricane Lamps (US$)	Annual savings from expenditures on Kerosene (US$)	Annual savings from expenditures on Kerosene (US$) with Annual Price Increase	Annual Saving from elimination of Battery Re-charging Costs (US$)	Annual Saving from flat battery used for TV (US$)
Col. 0	*Col. 1*	*Col. 2*	*Col.3*	*Col. 4*	*Col. 5*
0	0.00	0.00	0.00	0.00	0.00
1	0.00	60.78	62.61	40.86	0.00
2	0.00	60.78	64.48	40.86	0.00
3	0.00	60.78	66.42	40.86	80.16
4	3.41	60.78	68.41	40.86	0.00
5	0.00	60.78	70.46	40.86	0.00
6	0.00	60.78	72.58	40.86	80.16
7	0.00	60.78	74.76	40.86	0.00
8	3.41	60.78	77.00	40.86	0.00
9	0.00	60.78	79.31	40.86	80.16
10	0.00	60.78	81.69	40.86	0.00
11	0.00	60.78	84.14	40.86	0.00
12	3.41	60.78	86.66	40.86	80.16
13	0.00	60.78	89.26	40.86	0.00
14	0.00	60.78	91.94	40.86	0.00
15	0.00	60.78	94.70	40.86	80.16
16	3.41	60.78	97.54	40.86	0.00
17	0.00	60.78	100.47	40.86	0.00
18	0.00	60.78	103.48	40.86	80.16
19	0.00	60.78	106.58	40.86	0.00
20	3.41	60.78	109.78	40.86	0.00

Total Investment			Replacement Costs			
Downpayment (USD)	Loan (USD)	Voluntary Maintenance Agreement (USD)	Battery (USD)	Charge Controller (USD)	Lamps (USD)	Cable (USD)
Col. 6	*Col. 7*	*Col. 8*	*Col. 9*	*Col. 10*	*Col. 11*	*Col. 12*
57.04	0.00	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	8.51	19.86	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45

Saving from reduction of CO2 (US$)	Nominal Cash flows without carbon credit (US$)	PV_1 Cash flows without carbon credit (US$)	PV_2 Cash flows without carbon credit (US$)	Nominal Cash flows with carbon credit (US$)	PV_1 Cash flows with carbon credit (US$)	PV_2 Cash flows with carbon credit (US$)
Col. 13	*Col. 14 = Σ (Cost Savings - Cost)*	*Col. 15 = NPV = PV(B) - PV(C) r = 13%*	*Col. 16 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 17 = Σ (Cost Savings - Cost)*	*Col. 18 = NPV = PV(B) - PV(C) r = 13%*	*Col. 19 = NPV = PV(B) - PV(C) r = 6.35%*
0.00	-57.04	-57.04	-57.04	-57.04	-57.04	-57.04
2.66	-26.04	-23.05	-24.49	-23.38	-20.69	-21.99
2.66	-26.04	-20.40	-23.03	-23.38	-18.31	-20.67
2.66	25.74	17.84	21.40	28.40	19.69	23.61
2.66	100.79	61.82	78.79	103.45	63.45	80.87
2.66	-27.19	-14.75	-19.98	-24.52	-13.31	-18.03
2.66	149.18	71.65	103.10	151.84	72.93	104.94
2.66	97.39	41.40	63.29	100.05	42.53	65.02
2.66	100.79	37.91	61.59	103.45	38.92	63.22
2.66	149.18	49.66	85.72	151.84	50.54	87.25
2.66	-27.19	-8.01	-14.69	-24.52	-7.22	-13.25
2.66	97.39	25.39	49.48	100.05	26.08	50.83
2.66	152.58	35.20	72.89	155.24	35.82	74.16
2.66	97.39	19.88	43.74	100.05	20.43	44.94
2.66	97.39	17.60	41.13	100.05	18.08	42.26
2.66	24.60	3.93	9.77	27.26	4.36	10.83
2.66	100.79	14.26	37.64	103.45	14.64	38.63
2.66	97.39	12.19	34.20	100.05	12.53	35.13
2.66	149.18	16.53	49.25	151.84	16.83	50.13
2.66	97.39	9.55	30.23	100.05	9.81	31.06
2.66	-23.78	-2.06	-6.94	-21.12	-1.83	-6.17

Nominal Cash flows with kerosene price increase (US$)	PV_1 Cash flows with kerosene price increase (US$)	PV_2 Cash flows with kerosene price increase (US$)	Results without Carbon Credit (nominal)	Results with Carbon Credit (nominal)	Results with Kerosene Price Increase (nominal)	Results without Carbon Credit (PV_1)
Col. 20 = Σ (Cost Savings - Cost)	*Col. 21 = NPV = PV(B) - PV(C) r = 13%*	*Col. 22 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 23*	*Col. 24*	*Col. 25*	*Col. 26*
-57.04	-57.04	-57.04	Nominal: 1,349.90 IRR: 37.89%	Nominal: 1,403.11 IRR: 39.74%	Nominal: 1,816.51 IRR: 42.52%	NPV: 309.52
-24.22	-21.43	-22.77				
-22.34	-17.50	-19.75				
31.38	21.75	26.09				
108.42	66.50	84.76				
-17.50	-9.50	-12.87				
160.97	77.32	111.26				
111.36	47.34	72.37				
117.01	44.01	71.50				
167.70	55.83	96.36				
-6.28	-1.85	-3.39				
120.74	31.48	61.34				
178.46	41.17	85.25				
125.87	25.70	56.54				
128.55	23.23	54.29				
58.52	9.36	23.24				
137.55	19.46	51.36				
137.07	17.16	48.13				
191.87	21.26	63.35				
143.19	14.04	44.45				
25.22	2.19	7.36				

Results without Carbon Credit (PV_2)	Results with Carbon Credit (PV_1)	Results with Carbon Credit (PV_2)	Results with Kerosene Price Increase (PV_1)	Results with Kerosene Price Increase (PV_2)
Col. 27	*Col. 28*	*Col. 29*	*Col. 28*	*Col. 29*
NPV: 636.07	NPV: 328.20	NPV: 665.73	NPV: 410.47	NPV: 841.83

Source: Author.

Appendix 21: Calculations of NPV and IRR of 50 Wp SHS (Sensitivity Analysis)

Year	Annual savings from purchase of Hurricane Lamps (US$)	Annual savings from expenditures on Kerosene (US$)	Annual savings from expenditures on Kerosene (US$) with Annual Price Increase	Annual Saving from elimination of Battery Re-charging Costs (US$)	Annual Saving from flat battery used for TV (US$)
Col. 0	*Col. 1*	*Col. 2*	*Col.3*	*Col. 4*	*Col. 5*
0	0.00	0.00	0.00	0.00	0.00
1	0.00	30.39	31.30	40.86	0.00
2	0.00	30.39	32.24	40.86	0.00
3	0.00	30.39	33.21	40.86	80.16
4	3.41	30.39	34.21	40.86	0.00
5	0.00	30.39	35.23	40.86	0.00
6	0.00	30.39	36.29	40.86	80.16
7	0.00	30.39	37.38	40.86	0.00
8	3.41	30.39	38.50	40.86	0.00
9	0.00	30.39	39.65	40.86	80.16
10	0.00	30.39	40.84	40.86	0.00
11	0.00	30.39	42.07	40.86	0.00
12	3.41	30.39	43.33	40.86	80.16
13	0.00	30.39	44.63	40.86	0.00
14	0.00	30.39	45.97	40.86	0.00
15	0.00	30.39	47.35	40.86	80.16
16	3.41	30.39	48.77	40.86	0.00
17	0.00	30.39	50.23	40.86	0.00
18	0.00	30.39	51.74	40.86	80.16
19	0.00	30.39	53.29	40.86	0.00
20	3.41	30.39	54.89	40.86	0.00

Total Investment			Replacement Costs			
Downpayment (USD)	Loan (USD)	Voluntary Maintenance Agreement (USD)	Battery (USD)	Charge Controller (USD)	Lamps (USD)	Cable (USD)
Col. 6	*Col. 7*	*Col. 8*	*Col. 9*	*Col. 10*	*Col. 11*	*Col. 12*
57.04	0.00	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	8.51	19.86	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45

Saving from reduction of CO2 (US$)	Nominal Cash flows without carbon credit (US$)	PV_1 Cash flows without carbon credit (US$)	PV_2 Cash flows without carbon credit (US$)	Nominal Cash flows with carbon credit (US$)	PV_1 Cash flows with carbon credit (US$)	PV_2 Cash flows with carbon credit (US$)
Col. 13	*Col. 14 = Σ (Cost Savings - Cost)*	*Col. 15 = NPV = PV(B) - PV(C) r = 13%*	*Col. 16 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 17 = Σ (Cost Savings - Cost)*	*Col. 18 = NPV = PV(B) - PV(C) r = 13%*	*Col. 19 = NPV = PV(B) - PV(C) r = 6.35%*
0.00	-57.04	-57.04	-57.04	-57.04	-57.04	-57.04
1.33	-56.44	-49.94	-53.07	-55.11	-48.77	-51.82
1.33	-56.44	-44.20	-49.90	-55.11	-43.16	-48.72
1.33	-4.65	-3.22	-3.86	-3.32	-2.30	-2.76
1.33	70.40	43.18	55.04	71.73	44.00	56.07
1.33	-57.58	-31.25	-42.32	-56.25	-30.53	-41.34
1.33	118.79	57.05	82.10	120.12	57.69	83.02
1.33	67.00	28.48	43.54	68.33	29.04	44.41
1.33	70.40	26.48	43.02	71.73	26.98	43.83
1.33	118.79	39.54	68.25	120.12	39.98	69.02
1.33	-57.58	-16.96	-31.11	-56.25	-16.57	-30.39
1.33	67.00	17.47	34.04	68.33	17.81	34.71
1.33	122.19	28.19	58.37	123.52	28.50	59.01
1.33	67.00	13.68	30.09	68.33	13.95	30.69
1.33	67.00	12.10	28.30	68.33	12.35	28.86
1.33	-5.79	-0.93	-2.30	-4.46	-0.71	-1.77
1.33	70.40	9.96	26.29	71.73	10.15	26.79
1.33	67.00	8.39	23.52	68.33	8.56	23.99
1.33	118.79	13.16	39.22	120.12	13.31	39.66
1.33	67.00	6.57	20.80	68.33	6.70	21.21
1.33	-54.17	-4.70	-15.81	-52.84	-4.59	-15.42

Nominal Cash flows with kerosene price increase (US$)	PV_1 Cash flows with kerosene price increase (US$)	PV_2 Cash flows with kerosene price increase (US$)	Results without Carbon Credit (nominal)	Results with Carbon Credit (nominal)	Results with Kerosene Price Increase (nominal)	Results without Carbon Credit (PV_1)
Col. 20 = Σ (Cost Savings - Cost)	*Col. 21 = NPV = PV(B) - PV(C) r = 13%*	*Col. 22 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 23*	*Col. 24*	*Col. 25*	*Col. 26*
-57.04	-57.04	-57.04				
-55.52	-49.14	-52.21				
-54.58	-42.75	-48.26				
-1.83	-1.27	-1.52				
74.22	45.52	58.02	Nominal:	Nominal:	Nominal:	NPV:
-52.74	-28.62	-38.76	742.07	768.67	975.37	96.02
124.68	59.89	86.18				
73.98	31.45	48.08				
78.51	29.53	47.98				
128.05	42.63	73.58	IRR:	IRR:	IRR:	
-47.12	-13.88	-25.46	19.92%	20.61%	22.66%	
78.68	20.51	39.97				
135.13	31.18	64.55				
81.24	16.59	36.49				
82.58	14.92	34.88				
11.17	1.79	4.44				
88.78	12.56	33.15				
86.84	10.87	30.49				
140.13	15.53	46.27				
89.90	8.82	27.91				
-29.67	-2.58	-8.66				

Results without Carbon Credit (PV_2)	Results with Carbon Credit (PV_1)	Results with Carbon Credit (PV_2)	Results with Kerosene Price Increase (PV_1)	Results with Kerosene Price Increase (PV_2)
Col. 27	*Col. 28*	*Col. 29*	*Col. 28*	*Col. 29*
NPV: 297.17	NPV: 105.37	NPV: 312.01	NPV: 146.50	NPV: 400.05

Source: Author.

Appendix 22: Calculations of NPV and IRR of 50 Wp SHS (Scenario 2)

Year	Annual savings from purchase of Hurricane Lamps (US$)	Annual savings from purchase of Kupis Lamps (US$)	Annual savings from expenditures on Kerosene (US$)	Annual savings from expenditures on Kerosene (US$) with Annual Price Increase
Col. 0	*Col. 1*	*Col. 2*	*Col. 3*	*Col. 4*
0	0.00	0.00	0.00	0.00
1	0.00	0.28	60.78	62.61
2	0.00	0.28	60.78	64.48
3	0.00	0.28	60.78	66.42
4	1.70	0.28	60.78	68.41
5	0.00	0.28	60.78	70.46
6	0.00	0.28	60.78	72.58
7	0.00	0.28	60.78	74.76
8	1.70	0.28	60.78	77.00
9	0.00	0.28	60.78	79.31
10	0.00	0.28	60.78	81.69
11	0.00	0.28	60.78	84.14
12	1.70	0.28	60.78	86.66
13	0.00	0.28	60.78	89.26
14	0.00	0.28	60.78	91.94
15	0.00	0.28	60.78	94.70
16	1.70	0.28	60.78	97.54
17	0.00	0.28	60.78	100.47
18	0.00	0.28	60.78	103.48
19	0.00	0.28	60.78	106.58
20	1.70	0.28	60.78	109.78

Total Investment			Replacement Costs			
Downpayment (USD)	Loan (USD)	Voluntary Maintenance Agreement (USD)	Battery (USD)	Charge Controller (USD)	Lamps (USD)	Cable (USD)
Col. 5	*Col. 6*	*Col. 7*	*Col. 8*	*Col. 9*	*Col. 10*	*Col. 11*
57.04	0.00	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	0.00	0.00	0.00
0.00	127.69	0.00	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	8.51	19.86	26.45
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	0.00	8.51	19.86	0.00
0.00	0.00	4.26	0.00	0.00	0.00	0.00
0.00	0.00	4.26	98.13	0.00	0.00	26.45

Saving from reduction of CO_2 (US$)	Nominal Cash flows without carbon credit (US$)	PV_1 Cash flows without carbon credit (US$)	PV_2 Cash flows without carbon credit (US$)	Nominal Cash flows with carbon credit (US$)	PV_1 Cash flows with carbon credit (US$)	PV_2 Cash flows with carbon credit (US$)
Col. 12	*Col. 13 = Σ (Cost Savings - Cost)*	*Col. 14 = NPV = PV(B) - PV(C) r = 13%*	*Col. 15 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 16 = Σ (Cost Savings - Cost)*	*Col. 17 = NPV = PV(B) - PV(C) r = 13%*	*Col. 18 = NPV = PV(B) - PV(C) r = 6.35%*
0.00	-57.04	-57.04	-57.04	-57.04	-57.04	-57.04
2.66	-66.62	-58.96	-62.64	-63.96	-56.60	-60.14
2.66	-66.62	-52.18	-58.90	-63.96	-50.09	-56.55
2.66	-95.00	-65.84	-78.98	-92.34	-64.00	-76.77
2.66	58.51	35.89	45.74	61.17	37.52	47.82
2.66	-67.76	-36.78	-49.81	-65.10	-35.34	-47.85
2.66	28.43	13.66	19.65	31.09	14.93	21.49
2.66	56.81	24.15	36.92	59.47	25.28	38.65
2.66	58.51	22.01	35.76	61.17	23.01	37.38
2.66	28.43	9.47	16.34	31.09	10.35	17.87
2.66	-67.76	-19.96	-36.61	-65.10	-19.18	-35.17
2.66	56.81	14.81	28.86	59.47	15.50	30.21
2.66	30.14	6.95	14.40	32.80	7.57	15.67
2.66	56.81	11.60	25.52	59.47	12.14	26.71
2.66	56.81	10.26	23.99	59.47	10.74	25.12
2.66	-96.14	-15.37	-38.18	-93.48	-14.95	-37.12
2.66	58.51	8.28	21.85	61.17	8.66	22.84
2.66	56.81	7.11	19.95	59.47	7.45	20.88
2.66	28.43	3.15	9.39	31.09	3.45	10.27
2.66	56.81	5.57	17.64	59.47	5.83	18.46
2.66	-66.06	-5.73	-19.28	-63.40	-5.50	-18.51

Nominal Cash flows with kerosene price increase (US$)	PV_1 Cash flows with kerosene price increase (US$)	PV_2 Cash flows with kerosene price increase (US$)	Nominal Cash flows with Kerosene Price Increase and Carbon Credit	PV_1 Cash flows with kerosene price increase and Carbon Credit (US$)	PV_2 Cash flows with kerosene price increase and Carbon Credit (US$)	Results without Carbon Credit (nominal)
Col. 19 = Σ (Cost Savings - Cost)	*Col. 20 = NPV = PV(B) - PV(C) r = 13%*	*Col. 21 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 22 = Σ (Cost Savings - Cost)*	*Col. 23 = NPV = PV(B) - PV(C) r = 13%*	*Col. 24 = NPV = PV(B) - PV(C) r = 6.35%*	*Col. 25*
-57.04	-57.04	-57.04	-57.04	-57.04	-57.04	
-64.80	-57.34	-60.93	-62.14	-54.99	-58.43	
-62.92	-49.28	-55.63	-60.26	-47.19	-53.28	
-89.36	-61.93	-74.29	-86.70	-60.09	-72.08	
66.14	40.57	51.70	68.80	42.20	53.78	Nominal:
-58.08	-31.52	-42.69	-55.42	-30.08	-40.74	48.83
40.23	19.32	27.80	42.89	20.60	29.64	
70.78	30.09	46.00	73.44	31.22	47.73	
74.73	28.11	45.67	77.39	29.11	47.29	
46.96	15.63	26.98	49.62	16.52	28.51	IRR:
-46.86	-13.80	-25.32	-44.20	-13.02	-23.88	1.69%
80.17	20.90	40.73	82.83	21.59	42.08	
56.02	12.92	26.76	58.68	13.54	28.03	
85.29	17.41	38.31	87.95	17.96	39.50	
87.97	15.89	37.15	90.63	16.37	38.28	
-62.23	-9.95	-24.71	-59.57	-9.52	-23.66	
95.27	13.48	35.58	97.93	13.86	36.57	
96.49	12.08	33.88	99.15	12.42	34.82	
71.13	7.88	23.48	73.79	8.18	24.36	
102.61	10.06	31.86	105.27	10.32	32.68	
-17.06	-1.48	-4.98	-14.40	-1.25	-4.20	

Results with Carbon Credit (nominal)	Results with Kerosene Price Increase (nominal)	Results with Kerosene Price Increase and Carbon Credit (nominal)	Results without Carbon Credit (PV_1)	Results without Carbon Credit (PV_2)	Results with Carbon Credit (PV_1)	Results with Carbon Credit (PV_2)
Col. 26	*Col. 27*	*Col. 28*	*Col. 29*	*Col. 30*	*Col. 31*	*Col. 32*
Nominal: 102.03 IRR: 3.39%	Nominal: 515.43 IRR: 10.75%	Nominal: 568.63 IRR: 11.85%	NPV: -138.95	NPV: -85.45	NPV: -120.26	NPV: -55.79

Results with Kerosene Price Increase (PV_1)	Results with Kerosene Price Increase (PV_2)	Results with Kerosene Price Increase and Carbon Credit (PV_1)	Results with Kerosene Price Increase and Carbon Credit (PV_2)
Col. 33	*Col. 34*	*Col. 35*	*Col. 36*
NPV: -38.00	NPV: 120.30	NPV: -19.31	NPV: 149.97

Source: Author.

Appendix 23: Extracted Data from Monitoring Reports

Time Period	No Inspections	Category 1: Negligible (Total, %)		Category 2: Need Attention (Total, %)		Category 3: Immediate Action (Total, %)		Total Problems to be Reported (Total, %)	
Phase I									
May/Jun 07	112	16	15.00%	24	21.00%	4	4.00%	44	39.00%
Jul-07	128	4	3.00%	29	23.00%	6	5.00%	27	21.00%
Aug-07	96	5	5.00%	18	19.00%	5	5.00%	21	22.00%
Sep-07	100	10	10.00%	27	27.00%	5	5.00%	37	37.00%
Oct-07	118	20	17.00%	8	7.00%	6	5.00%	26	22.00%
Nov-07	75	9	12.00%	10	13.00%	0	0.00%	15	20.00%
Dec 07	112	8	7.00%	21	19.00%	1	1.00%	27	24.00%
Jan-08	124	15	12.00%	22	18.00%	2	2.00%	32	26.00%
Feb-08	173	17	10.00%	63	36.00%	9	5.00%	69	40.00%
Mar 08	109	13	12.00%	42	39.00%	1	2.00%	49	45.00%
Apr-08	53	9	17.00%	4	8.00%	0	0.00%	11	21.00%
May 08	75	9	12.00%	10	13.00%	0	0.00%	15	20.00%
Jun-08	88	4	5.00%	40	45.00%	4	5.00%	45	51.00%
Jul-08	133	9	7.00%	28	21.00%	7	5.00%	42	32.00%
Aug-08	79	10	13.00%	55	70.00%	10	13.00%	61	77.00%
Total Phase I	**1575**	**158**	**10.03%**	**401**	**25.46%**	**60**	**3.81%**	**521**	**33.08%**
Phase II – New SHS									
Nov-09	68	10	15.00%	15	22.00%	8	12.00%	33	49.00%
Dec 09	119	15	13.00%	29	24.00%	13	11.00%	57	48.00%
Jan-10	195	14	7.00%	102	52.00%	58	30.00%	174	89.00%
Feb-10	265	2	1.00%	130	49.00%	4	2.00%	136	52.00%
Mar 10	327	11	3.00%	260	80.00%	17	5.00%	288	88.00%
Apr-10	236	2	1.00%	219	93.00%	3	1.00%	224	95.00%
May 10	302	6	2.00%	260	86.00%	7	2.00%	274	91.00%
June 10	389	14	4.00%	343	88.00%	7	2.00%	361	93.00%
Total New SHS	**1901**	**74**	**3.89%**	**1358**	**71.44%**	**117**	**6.15%**	**1547**	**81.38%**
Phase II – Old SHS									
Nov-09	134	8	6.00%	46	34.00%	34	25.00%	88	66.00%
Dec 09	122	4	3.00%	42	34.00%	14	11.00%	60	49.00%
Jan-10	58	3	5.00%	38	66.00%	14	24.00%	55	95.00%
Feb-10	124	1	1.00%	64	51.00%	1	1.00%	66	53.00%
Mar 10	92	3	3.00%	68	74.00%	8	9.00%	79	86.00%
Apr-10	42	0	0.00%	37	88.00%	5	12.00%	42	100.00%

May 10	101	1	1.00%	84	83.00%	13	13.00%	98	97.00%
Jun 10	59	1	2.00%	49	83.00%	7	12.00%	57	97.00%
Total Old SHS	**732**	**21**	**2.87%**	**428**	**58.47%**	**96**	**13.11%**	**545**	**74.45%**
Total	**4208**	**253**	**6.01%**	**2187**	**51.97%**	**273**	**6.49%**	**2613**	**62.10%**

Source: Author based on data from Wiese et al. (2007a; 2007b; 2007; 2008a; 2008b; 2008; 2009a; 2009; 2010a; 2010).

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